GEOLOGY AND LANDSLIDE SUSCEPTIBILITY MAPPING ALONG MAJOR ROAD USING GEOGRAPHIC INFORMATION SYSYTEM (GIS) AT KAMPUNG SUNGAI RUAL, JELI, KELANTAN

By

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A report submitted in fulfilment of the requirements for the degree of Bachelor of Applied Science (Geoscience) with Honours

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DECLARATION

I declare that this thesis entitled Geology and Landslide Susceptibility Mapping Along Major Road Using Geographical Information System (GIS) At Kampung Sungai Rual, Jeli, Kelantan is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I/ We hereby declare that I/ we have read this thesis and in my/our opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Applied Science (Geoscience) with Honours.

Signature :

____

Name of Supervisor : Rohazaini Binti Muhammad Jamil

Date :

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Geology And Landslide Susceptibility Mapping Along Major Road Using Geographical Information System (GIS) At Kampung Sungai Rual, Jeli, Kelantan,

ABSTRACT

Landslides are more prevalent than any other geological occurrence, and they can occur anywhere on the globe. Each year, landslides are one of the most prominent geohazards that cause enormous losses. The causes of landslides in Malaysia differ significantly from the rest of the world. Some studies suggest that geological conditions are the leading cause of slope failure in many countries around the world. Thus, this research has chosen Kampung Sungai Rual, in Jeli district, Kelantan to perform a landslide study. The coordinate of the study area is between 5°40°49.06'N 101° 47'29.66''E (top left); 5°4048.70'N 101°50'44.64''E (top right), and 5°38'34.09'N 101° 50'44.28''E (bottom left); 5°38'34.22'N 101°47'30.06''E (bottom right) that covers an area of 25km^2. The purpose of the study is to produce geological map of Kampung Sungai Rual, Jeli Kelantan with the scale of 1:25000, to identify parameters that influence landslides and eventually to generate landslides susceptibility map using ModelBuilder tool in ArcGIS. This study also discusses the geomorphology, stratigraphy, structural geology, and historical geology of the study area. Rual River is located in Jeli district, which is positioned at the foot of Peninsular Malaysia's Main Range. The distribution of rocks found in the study area is igneous rock and metamorphic rock, according to research and data collection during mapping. The highest peak in the study area is an igneous rock hill with a height of 800m from mean sea level. To obtain a more accurate rock type, rock samples were collected and sent to a laboratory for petrographic analysis. The parameters that triggered the occurrence of landslide were identified; distance to stream, distance to road, lithology, slope, aspect, and land use. The data of Digital Elevation Model (DEM) had been used to extract the parameters information. Following this, a Geographic Information System (GIS) based on ModelBuilder was utilised to create the landslide susceptibility map. The result indicated that the susceptibility map for landslides is divided into three classes: low, moderate, and high. The region is more vulnerable to landslides as class levels increase. Based on the results, it can be concluded that the area under study belongs to a low susceptibility class and that the likelihood of a landslide occurring is low.

Keywords: Landslide, Parameters, ModelBuilder, Sungai Rual, Geographic Information System (GIS), Petrographic analysis

Geologi Dan Pemetaan Kecenderungan Tanah Runtuh Di Sepanjang Jalan Utama Menggunakan Sistem Maklumat Geografi (GIS) Di Kampung Sungai Rual, Jeli, Kelantan,

ABSTRAK

Tanah runtuh lebih berleluasa daripada kejadian geologi lain, dan ia boleh berlaku di mana-mana sahaja di dunia. Setiap tahun, tanah runtuh adalah salah satu geobencana yang paling ketara yang menyebabkan kerugian yang besar. Punca-punca tanah runtuh di Malaysia berbeza dengan ketara daripada negara lain di dunia. Beberapa kajian mencadangkan bahawa keadaan geologi adalah punca utama kegagalan cerun di banyak negara di seluruh dunia. Justeru, kajian ini telah memilih Kampung Sungai Rual, dalam daerah Jeli, Kelantan untuk melakukan kajian tanah runtuh. Koordinat kawasan kajian adalah antara 5°40°49.06'N 101° 47'29.66"E (kiri atas); 5°4048.70'N 101°50'44.64"E (atas kanan), dan 5°38'34.09 'N 101° 50'44.28"E (kiri bawah); 5°38'34.22'N 101°47'30.06"E (kanan bawah) yang meliputi kawasan seluas 25km2. Tujuan kajian adalah untuk menghasilkan peta geologi Kampung Sungai Rual, Jeli Kelantan dengan skala 1:25000, untuk mengenal pasti parameter yang mempengaruhi tanah runtuh dan akhirnya menjana peta kerentanan tanah runtuh menggunakan alat modelBuilder dalam ArcGIS. Kajian ini juga membincangkan tentang geomorfologi, stratigrafi, geologi struktur, dan geologi sejarah kawasan kajian. Sungai Rual terletak di daerah Jeli, yang terletak di kaki Banjaran Utama Semenanjung Malaysia. Taburan batuan yang terdapat di kawasan kajian ialah batuan igneus dan batuan metamorf, menurut kajian dan pengumpulan data semasa pemetaan. Puncak tertinggi di kawasan kajian ialah bukit batu igneus dengan ketinggian 800m dari purata paras laut. Untuk mendapatkan jenis batuan yang lebih tepat, sampel batuan dikumpul dan dihantar ke makmal untuk analisis petrografi. Parameter yang mencetuskan kejadian tanah runtuh dikenal pasti; jarak ke sungai, jarak ke jalan, litologi, cerun, aspek, dan guna tanah. Data Model Ketinggian Digital (DEM) telah digunakan untuk mengekstrak maklumat parameter. Berikutan itu, Sistem Maklumat Geografi (GIS) berdasarkan ModelBuilder telah digunakan untuk mencipta peta kerentanan tanah runtuh. Hasil kajian menunjukkan bahawa peta kerentanan tanah runtuh dibahagikan kepada tiga kelas: rendah, sederhana dan tinggi. Wilayah ini lebih terdedah kepada tanah runtuh apabila tahap kelas meningkat. Berdasarkan keputusan tersebut, dapat disimpulkan bahawa kawasan yang dikaji tergolong dalam kelas kerentanan yang rendah dan kemungkinan kejadian tanah runtuh adalah rendah.

Kata kunci: Tanah runtuh, Parameter, ModelBuilder, Sungai Rual, Sistem Maklumat Geografi (GIS), Analisis petrografi

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LIST OF ABBREVIATIONS

DEM	Digital Elavation Model
GIS	Geographic Information System
GPS	Global Positioning System
USGS	US Geological Survey Earth Resources and Science Centre
WOM	Weighted Overlay Method
AHP	Analytical Hierarchy Process
WLC	Weightage Linear Combination
SMCE	Spatial Multi-Criteria Evaluation

LIST OF SYMBOLS

°	Degree
%	Percentage
’	Minutes
”	Second

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Geological mapping is the process of collecting and recording geological information from rocks that are visible at the surface. This typically involves a geologist going into the field to gather data, and then using that data to create a map that illustrates various geological features and characteristics. Geologic mapping is a highly interpretive and scientific process that can be used for a wide range of applications, such as assessing groundwater quality and contamination risks, predicting hazards like earthquakes, volcanic eruptions, and landslides, identifying and evaluating energy and mineral resources, determining the cost of extracting those resources, selecting sites for waste repositories, and managing land use. Additionally, geologic maps can play a critical role in public and private decision-making, such as determining the best locations for landfills or highways, by providing detailed information that can help minimize uncertainty and reduce costs. (David, 2004).

Even though Malaysia is not a mountainous nation, with mountains and hills accounting for less than 25% of its total territory, landslides and slope collapses are common. A landslide is an example of a natural catastrophe. A landslide is a mass movement of rock, debris, or soil down a slope caused by gravity (Akter et al., 2019). Precipitation, storms, water activities, and improper slope management are the primary causes of landslides and slope collapse in Malaysian hillside development. Misapplication of prescriptive methodologies, insufficient investigation of previous failures, and design flaws, such as insufficient site-specific ground studies, may all contribute to landslides. Landslides are a major geological danger that may occur in practically any country. Every year, landslides cost billions of dollars in damage and kill or injure hundreds of people throughout the world (Akter et al., 2019).

Landslides can have severe impacts on human life and the economy of many countries. One way to mitigate the risk of landslides is by providing risk managers with up-to-date, accurate, and reliable information about where landslides are likely to occur. This is where susceptibility mapping comes in - it can provide valuable insights for a wide range of stakeholders, such as corporate and public sector users, government organizations, and the scientific community. By identifying areas that are at higher risk of landslides, susceptibility mapping can help decision-makers take proactive measures to protect people and property. Additionally, susceptibility mapping can be used on a local, national, and global scale, making it a useful tool for mitigating landslide risk on a large scale.

Landslide susceptibility mapping was also carried out using Saaty's Analytical Hierarchy Process (AHP) data from the previous study, which contains the Weighted Linear Combination (WLC) Spatial Multi-Criteria Evaluation (SMCE) (Shahabi & Hashim, 2015). Each method is backed up by a distinct set of logical arguments. This method may provide objective mapping of landslide threat, eliminating the subjectivity of experts. The integration of landslide susceptibility maps produced using AHP, WLC, and SMCE techniques for the creation of landslide susceptibility mapping in the Kelantan region of Kampung Sungai Rual using GIS and remote sensing data is thus the primary difference between previous studies and the current one.

The purpose of this study is to use a Geographic Information System to map landslide susceptibility in the Kampung Sungai Rual region (GIS). The expected landslide susceptibility map were created using a GIS overlay and raster computation (modelBuilder tool).

1.2 Study Area

This research will be conducted in Kampung Sungai Rual, Jeli, Kelantan in Jeli district is one out of ten districts in Kelantan. It is also located in the western part of the state (Nazaruddin, 2015). The area of the study area is about 25 km². The coordinate on the top left is 5°40'49.06''N 101° 47'29.66''E, on right is 5°40'48.70''N 101°50'44.64''E, on the bottom left 5°38'34.09''N 101° 50'44.28''E and on the bottom right 5°38'34.22''N 101°47'30.06''E. Within the area, there are villagers in the study area, one main river and a few high elevation areas. There is only one main route that connects Kampung Sungai Rual, there to Bandar Jeli and Jalan Lata Janggut.

1.2.1 Location

The location of the Kampung Sungai Rual a show in the Figure 1.1 with the coordinate 5°39'15.5''N 101°47'39.5''E. Located in Jeli district. The Jeli population is 40637. Agriculture in the area such as rubber, oil palm, bananas, vegetables are cultivated there.

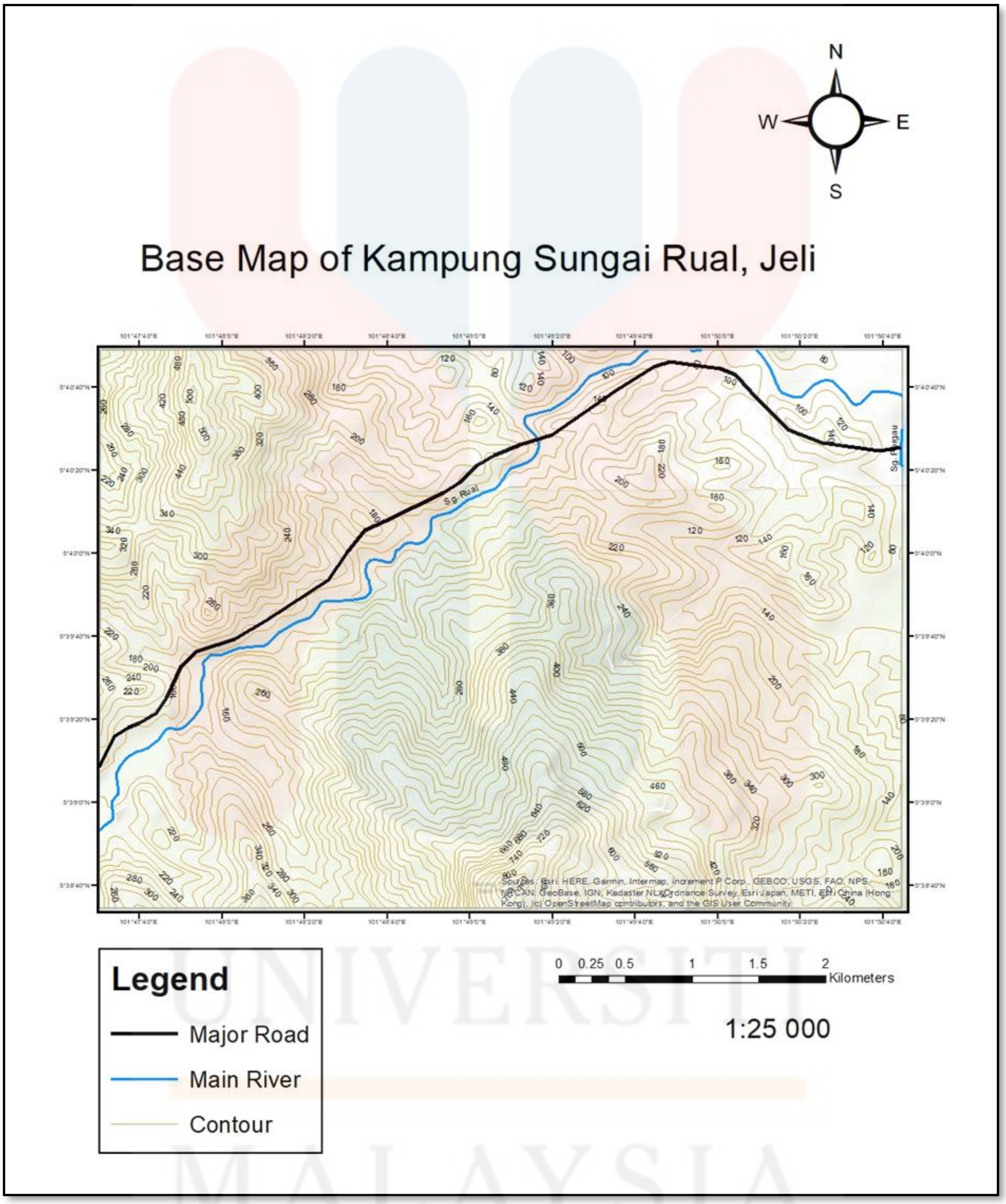


Figure 1: Sungai Rual, Jeli map (Source: topo map/base map in ArcGIS software).

1.2.2 Road connection/accessibility

The study area is located at Kampung Sungai Rual, Kelantan. Along the road that goes from Jeli town to Kampung Berdang is about 9 km and should take about 15 minutes. Besides, there is only one main route that connect Kampung Sungai Rual to Bandar Jeli and Jalan Lata Janggut.

1.2.3 Demography

According to the Malaysian Department of Statistics, there were 54,656 people living in Jeli in year 2020. The population of the Jeli region is shown from the year 2000 to the year 2020 in Graph 1.1. Jeli has a population density of 41people per square kilometre on its 1,330 square kilometres of land. Agriculture, commerce, hospitality, and marketing are all thriving in this area, creating a steady demand for new residents.

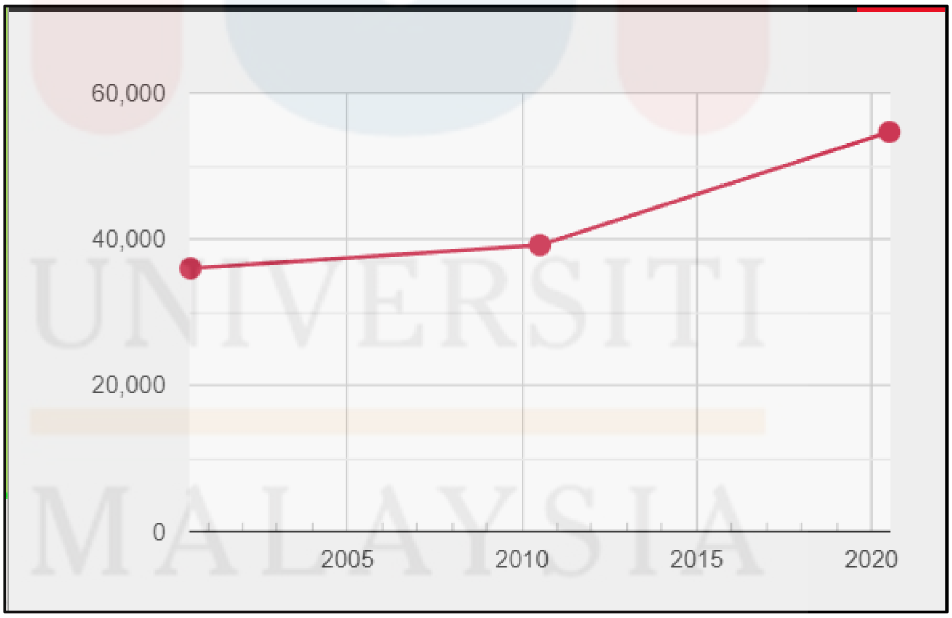


Figure 1.1: Population Range in Jeli from year 2000 to 2020 (Source: Department of Statistics Malaysia, 2020).

1.2.4 Land use

There is a wide variety of land applications. In rural regions, agriculture is a frequent land use, whereas commercial and residential development predominates in urban areas. Land usage also impacts local human activities and vocations. The majority of Jeli's territory is allocated to rubber, oil palm, and forest plantations. Rapid population increase in Jeli has led to significant shifts in the city's land use patterns. The principal land uses in the region of study are oil palm and rubber plantations, forests, and a tiny human population.

1.3 Problem Statement

The geological data in the study area has least geomorphological information. The updated geologic maps of the study area can be created through geological mapping and observation. Thus, this study is proposed to update the geological map of designated study area to keep updating the current geologic condition (Shahabi & Hashim, 2015).

Since landslides are an unanticipated threat in Jeli, this research was done to investigate the issue of landslides in the study area. It can strike at any time and do a significant amount of damage. Landslides can also be caused by human activities that are not managed. These activities are to blame for the deterioration in the quality of the environment. Despite the fact that landslides happen on a fairly frequent basis in Malaysia, hilly and mountainous regions are in desperate need of landslide studies. This is because preparedness and mitigation operations are not operating well in many places. As a result of this research, the potential susceptibility region will be projected, which will make it possible to lower the level of ignorance that exists among the locals.

1.4 Objectives

The goals of this research:

1. To produce geological map of Kampung Sungai Rual, Jeli Kelantan with scale 1:25000.
2. To identify the parameters that influence landslides in the study area
3. To generate a landslide susceptibility map using ModelBuilder tool in ArcGIS.

1.5 Scope of Study

In order to achieve the goals of this study, geological mapping and observation are required to gather geological data from the region under investigation to create a geological map. Secondary data is also required to complete the geological mapping. The area is 25 km^2 in size.

This study also includes a map of the region's landslide risk. A raster-based GIS will be used to construct the landslide susceptibility map, which include the following parameters: lithology, aspect, Land use, distance to road, distance to stream, and slope map. The GIS will then create a strategy for parameter overlaying as well as a raster calculation.

1.6 Significance of Study

Geological mapping is one of the most effective methods for determining the geological characteristics of a place in great detail. This is due to the geological features' capacity to undertake more detailed geological mapping.

Meanwhile, generating a landslide susceptibility map form the geological characteristics of the study area is one of applications that help us to understand more about geohazards of the particular area. The most vulnerability area may be found by creating a map of landslide susceptibility. The key to effectively estimating a landslide is to have continuous, accessible, and precise data on its occurrence. The accuracy of landslide susceptibility maps is critical because it may help disaster planners, local governments, and decision-makers avert loss of life and property. Otherwise, precise susceptibility mapping on a local and worldwide scale may be critical information for a wide range of corporate and public sector customers, government organisations, and the scientific community (Shahabi & Hashim, 2015).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, it covers the literature review of the prior research that has been done in the region around the study area, or research that is similar to research that was used by the researchers who came before us. In order to provide support for the technique and process that were utilised to achieve the aim of this study, the literature review is to undertake a review of the existing relevant research. This chapter examined the regional geology, including the stratigraphy and structural geology of the Kampung Sungai Rual area, along with a specification (landslides study).

2.2 Regional Geology and Tectonic Setting

Kelantan's geology consists of sedimentary and metasedimentary rocks flanked by Main Range and Boundary Range granites.. The batholith DIu Lalat (Senting), the Stong Igneous Complex, and the pluton Kemahang are the most conspicuous granitic intrusive windows in the central zone. These granite and country rock belts are basically the northern extension of Pahang's north-south trending regional geology. In western and central Kelantan, the belts extend northward into southern Thailand, while the Boundary Range granite lies under the alluvial coastal plain of Sungai Kelantan in the east. Amphibolite and serpentinite are uncommon minerals (Khoo, 1983).

The state's oldest rocks are found in a northward-trending region bordering the Main Range foothills and extending east to Sungai Nenggiri. The majority is made up of metapelites with little fragmentation caused by volcanism and calcareous and arenatic intercalations. Mostly Permian volcanic-sedimentary rocks occur abundantly and awkwardly on the Lower Paleozoic succession in southwest Kelantan. The Taku Schist, whose date is still being debated but is clearly pre-Triassic, is found in the central and northern parts of Kelantan (Khoo, 1983).

The Taku Schist Formation is a clastic Carboniferous-Permian rock in the southern Transect area. The majority of the formations are made up of completely crystalline, schistoned schists. The Taku schist formation is dominated by mica schist, which includes quartz-mica schist, mica-garnet schist, and quartz-mica-garnet schist. Taku Schist refers to a kind of metamorphic rock found in central Kelantan (McDonald, 1967).

Taku schist was called after a particularly remarkable outcrop discovered near the Sungai Taku. The majority of these rocks are schist, which is fully crystalline and often schistose. The Taku Schist is composed mostly of Permo-Triassic rocks, with probable inclusions of Carboniferous-era strata, according to (Khoo, 1983). On both its western and eastern sides, greenschist-facies strata of the same age as the Taku Schist surround it.

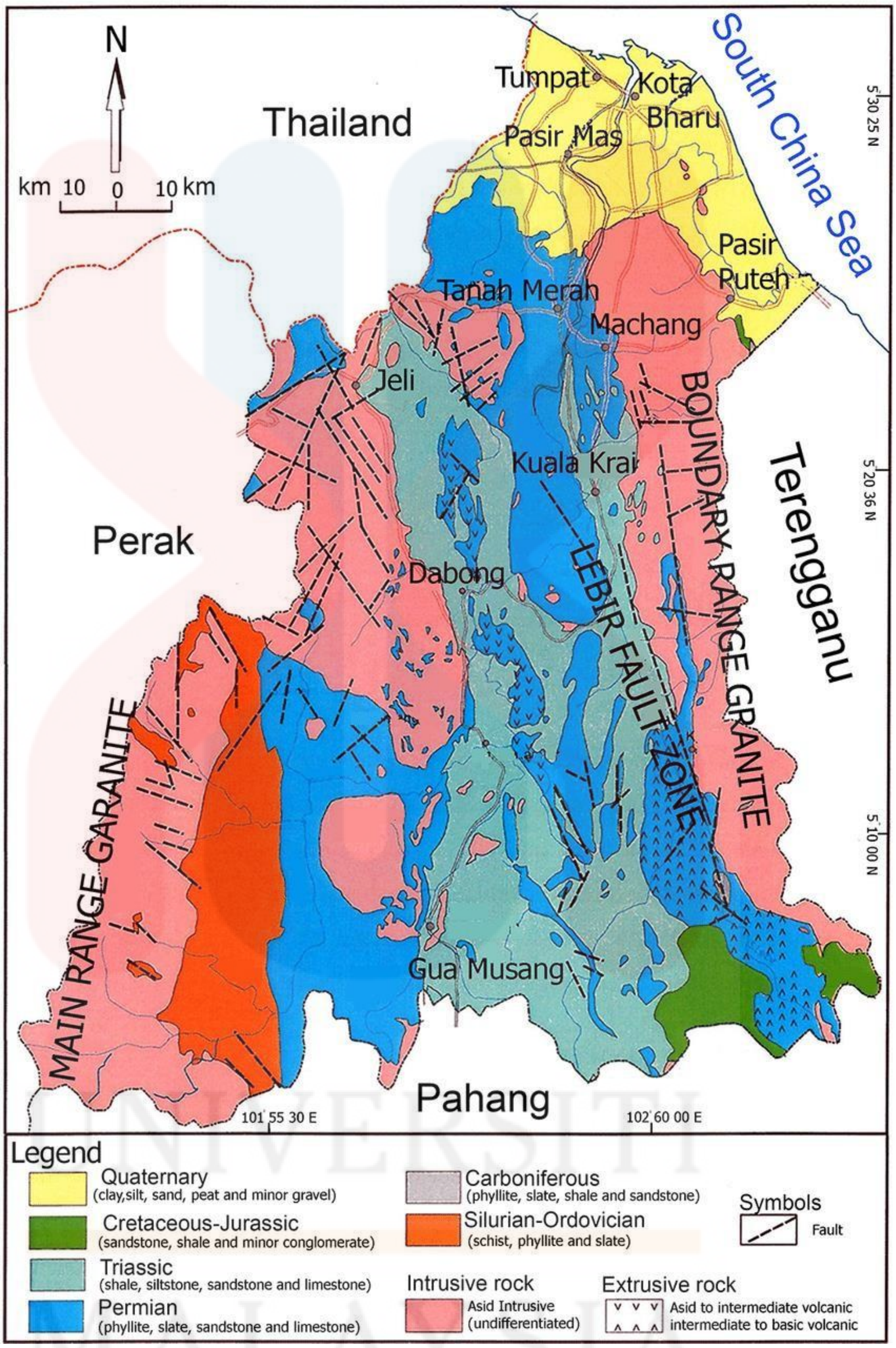


Figure 2.1: The Geological Map of Kelantan

2.3 Stratigraphy

According to Kelantan's general geology (JMG, 2003), the Jeli district is composed of three different types of rocks: phyllite, slate, sandstone, and limestone from the Permian (Gua Musang Formation); shale, siltstone, and limestone from the Triassic (Gunong Rabong Formation); and granitic rocks from the Granitic rock group (acid intrusive). Based on its geomorphology, the landscape of Kelantan may be split into four distinct types that are mountainous, hilly, plain, and coastal (Tanot et al,2001). Mountainous topography may be found in the western and northern parts of the area. This terrain is composed of the granite and schist of the Main Range and the Stong Migmatite Complex. The central and eastern parts of the region have a flat topography. Peninsular Malaysia saw extensive faulting and folding as a result of tectonic activity throughout the Paleozoic and Mesozoic periods. Localized features include things like folds, joints, and faults in sedimentary rocks and things like joints and faults in granitic rocks (JMG,2003). Local structures dominate the landscape of Kelantan in the north-south and northwest-southeast directions. The main local buildings in the Jeli area, on the other hand, are located along the NE-SW and NW-SE lines (Dony,2017).

2.4 Structural Geology

Peninsular Malaysia is stretched north-northwesterly in accordance with its longitudinal extent pattern (Hutchison & Tan, 1989). Structures on the Peninsular's surface defined the north-eastern direction pattern and, later, the north-northwest strike direction. Permian folding has been discovered in the northwest corner of the Peninsula (Khoo and Tan, 1983).

The unique western and eastern vergences of the central belt were thought to have formed as a result of the general eastern-western compression caused by the collision of the Late Triassic crust (Hutchison & Tan, 1989). Peninsular Malaysia's structural makeup eventually included massive faults crammed with massive multi-phase quartz dykes. This grain is found in the country's northwest-southeast region (Hutchison & Tan, 1989).

2.5 Historical Geology

Kelantan is part of the Eastern Belt of Peninsular Malaysia. From east Kelantan to Terengganu and east Pahang to southeast Johor, you can find sediments that range in age from the Carboniferous to the Permian. From the eastern foothills of the main range to its eastern limit, marked by the Lebir Fault in the north and the western frontier of the Dohol Formation in the south, the intermediate belt constituted the western barrier, extending from Kelantan to Johor. Mesozoic sediments are formed by carboniferous calcareous rocks along the eastern and central belt boundaries. West Pahang, the heart of the upper Paleozoic rock in the Gua Musang, is host to the Aring Formation, the Taku Schist, and the Raub group (Hutchison, 2014).

2.6 Landslide in Malaysia

A landslide is a common natural catastrophe that may result in the loss of property and life. Multiple severe and moderate landslides ravaged Malaysia, killing up to 500 people and causing significant property damage, multi-story structure collapses, road and highway damage, and natural resource loss (Akter et al., 2019). Every year, two to eight landslides occur, with one to seven resulting in fatalities and property damage. Landslides were responsible for more than 13.9 percent of all deaths between 1990 and 2014 (National Slope Master Plan, 2009). Malaysia's growing urbanisation and economic progress have caused landslide damage and losses. Many firms have migrated to the highlands and places with steep terrain due to a shortage of acceptable low-lying sites. High-rise building development on mountain slopes and in hilly terrain increases the danger of landslides (Akter et al., 2019).

According to the study on landslide susceptibility in Kelantan by Hashim et al. (2017), the primary causes of landslides are slope, aspect, soil, lithology, and precipitation volumes. Precipitation quantities, according to the study, are the major cause of landslides. Floods occurred in Kelantan, Malaysia, in 2014 was due to the unequal distribution of precipitation. Land use and development along slopes are the second-largest factors to landslide activity. Human activities such as illegal logging in the forest, agricultural operations, and slope building may also cause landslides.

2.7 Type of Landslide

Ground materials may fail, move, or deform in a variety of ways. Sliding down a curved plain creates spinning slumps, which are blocks of slumps. The downhill slope motion of earth materials along a slip plane, such as a bedding plane or fissure, is known as translational sliding. The free fall of earthen debris from the exposed face of a cliff is referred to as rock fall. Flows are the downward movement of unconsolidated materials through which particles flow and mix. Creep is the slow movement of rock or dirt. A rapid flow may include dirt, sludge, or debris. A debris avalanche is a fast to extremely fast debris flow. A huge debris avalanche has the potential to inflict major damage and perhaps death. Lateral spreading is a kind of landslide that occurs on almost level or mild slopes. Typically, it starts suddenly and then expands gradually and steadily. Subsidence is the sinking of a mass of soil under the surrounding surface, which may happen on either sloping or level land (Keller, 2008). Landslides may have intricate sliding and flow patterns. When saturated with water, earth flows from the slope's bottom, weakening the higher part and causing earth blocks to fall. A landslide may have killed or injured many nearby neighbours in an instant.

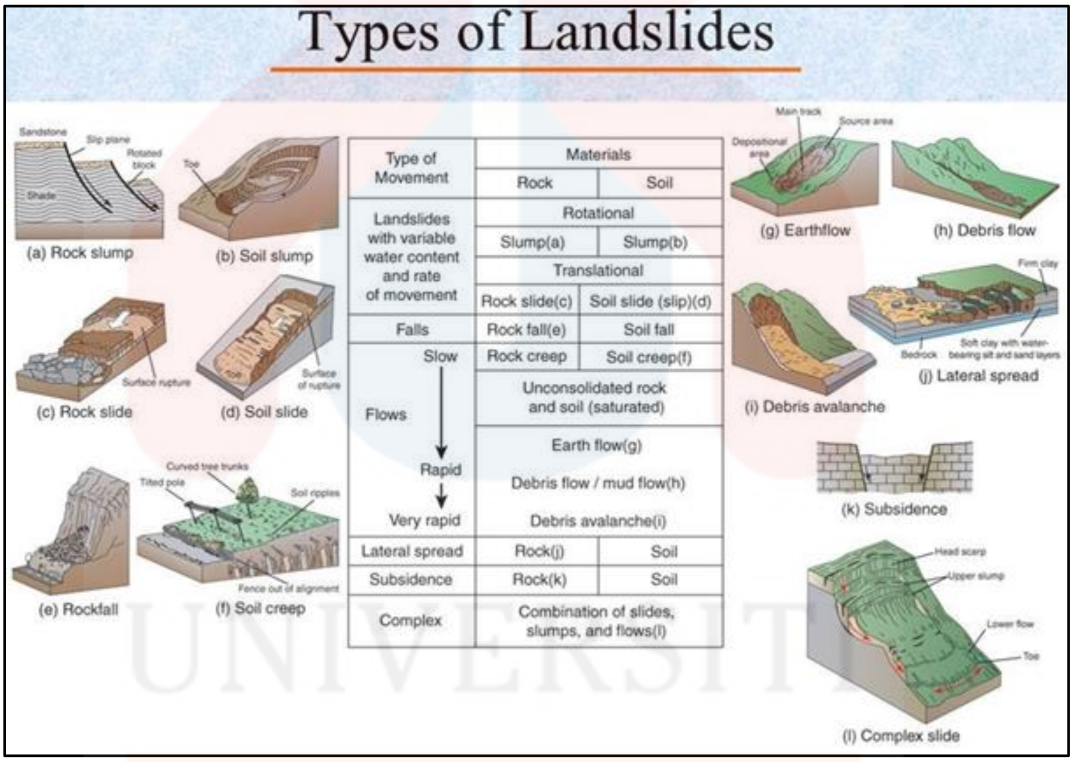


Figure 2.2: Type of landslides (Source: Pearson Prentice Hall, 2008)

2.8 GIS in Landslide Susceptibility Mapping

The Geographic Information System (GIS) is an important tool for modelling and depicting processes that are typical of the world by employing the geographical dimension and its connections to other dimensions (Salehi & Ahmadian, 2017). GIS is used in practically every academic subject. The wording alone implies the need of considering location in slope and risk assessments. GIS, on the other hand, can do much more than calculate distances and provide mapping solutions.

Landslide susceptibility maps may be created using a variety of GIS techniques. Prior research used a landslide inventory as its technique. Landslide inventory maps record the locations and features of previous landslides, but they seldom include information on the triggering process. As a result, inventory maps may be used to estimate the geographical distribution of current landfill sites as well as the possibility of future landfill slides (Shahabi & Hashim, 2015).

2.9 Geographic Information System (GIS) application

The Geographical Information System is the main tool for finishing this study on natural hazard assessment. Based on the study, there are benefits and drawbacks to this tool. The use of a geographic information system is necessary in order to analyse the risk of landslides in a systematic and effective manner. There are many different elements that might affect the frequency of landslides, thus a Geographic Information System (GIS) could be utilised to make themed map layers. The data includes the angle of slope, the lithology, the land use, the distance to the road, the fault, and the stream. This means a lot of data may be stored in the GIS tool. The Geographic Information System (GIS) is a tool for storing, organising, managing, and accessing data for use in subsequent research. The data includes such things as the slope angle, lithology, land use, proximity to a road or fault, and distance to a stream. Maps, charts, graphs, and tables are all effective ways to display data. It is possible to combine GIS and Excel data for statistical analysis.

Creating a map of landslide susceptibility involves combining and layering various factors that affect the likelihood of landslides. This includes the angle of the slope, the composition of the rock, the use of the land, the proximity to roads and faults, and the distance from streams. These factors are combined and analyzed using GIS techniques to produce a map that can be presented in either raster or vector format. The resulting map can be queried to reveal specific attributes and spatial relationships, making it a valuable tool for identifying areas at risk for landslides. The process of creating such a map can be time-consuming, especially when it comes to digitization, but GIS allows for efficient and comprehensive study of a large area.

Additionally, there are drawbacks to using GIS to complete the landslide assessment study. There are three classes in this study that can be read: low, moderate, and high. Although there are high landslides in the study area, the data can still be found. The use of GIS is then required, which takes a lot of time. This is due to the fact that the maps will need to be intersected, merged, and digitally clipped in order to complete this research. Additionally, the database needs to convert from raster to vector format due to the incompleteness of the data, and the data cannot be integrated without conversion.

The Landslide Susceptibility Map was created using a variety of methods, according to the researchers. The Analytic Hierarchy Process (AHP), one of them, is utilised in this research area. AHP basically consists of breaking down complex, unstructured situations into their component parts, organising these parts or variables into a hierarchy of importance, and synthesising the judgments to determine which variables should be used to influence the outcome of the situation. This approach utilises a hierarchical structure and informed judgement or expert opinion to quantify and synthesise a solution to the relative value or contribution of many characteristics in order to abstract, organise, deconstruct, and regulate the complexity of decisions involving several attributes (Shahabi & Hashim, 2015)

In conclusion, the study was conducted to build a database for land-slide risk mapping in the region. Technology used in this study included a Geographic Information System (GIS), a crucial desktop study technique for analysing landslides, and was integrated with databases using this system as a framework. A landslide vulnerability map, depicting the potential severity of future landslides in the study area, has also been developed.

2.10 Weighted Overlay Method (WOM)

Weighted overlay is a method that uses integer raster data to evaluate numerous input values in the same context. As a result, before the operation can be carried out, the floating point raster data must be converted to integer raster values. The weighted overlay technique is used to analyse several input values in the same context. Before utilising a weighted overlay strategy, the characteristics of each layer must be sorted from best to worst. The next step is to give each class a point total, with the most suitable class earning the most points. The amount of class points reduces as the degree of appropriateness lowers. Inappropriate locations should be restricted, and the scale adjusted appropriately. A weighted overlay can only employ integer raster data. As a result, before proceeding with the method, the floating point raster data must be converted to integer raster values. To choose the data categories that will be utilised in the same process, a weighted overlay method was applied (Cabuk, et, 2010).

2.11 ModelBuilder

ModelBuilder is a graphical programming-based language for developing geoprocessing workflows. Geoprocessing models have the potential to automate and record geographical analysis and data management activities. ModelBuilder enables users to create and modify geoprocessing models. A model is a graphical representation that logically connects processes and geoprocessing tools. One process's output becomes the input for another (ArGIS Pro, 2022).

One or more geoprocessing actions might be shown in the model diagram. Each process is made up of an instrument and the values that it specifies (e.g., input and output data, reclassification table). Model components such as inputs (geographic data, values, or SQL expressions), outputs (geographic data or values generated when the model runs), tools (operations to be performed on the input data), connecting arrows that indicate the processing sequence, and text labels that describe the model are represented by symbols in the ModelBuilder interface. Geoprocessing tools for complicated processes may be ready-to-use ArcGIS system tools, Python scripts or other COM-compliant languages, or embedded models. To create a model, just drag and drop model components into the ModelBuilder window, connect them with arrows, and arrange the model components in the desired sequence. The parameters of a model must be specified before it can be executed. Wizards, layout preparation, drag-and-drop tools, property sheets, and the ability to save the whole model as an XML file or script are all included in ModelBuilder (ESRI, 2000).

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

Certain materials and procedures are used to complete the process of collecting data and critical information for geological interpretation and for the study of landslide potential. The task should be smoother when the proper materials and procedures are applied.

3.2 Materials

3.2.1 Geological Mapping

A geologist in the field records all geological information relating to rocks that are exposed at the surface. Prior to formal geological interpretation, geological mapping will employ a base map (topographic map) to capture field coordinates, strikes and dips, and traverses, as well as data and information on the study area. Outcrop samples are smashed in the field using a geological hammer with a pick-head. The Garmin Portable Global Positioning System (GPS) is used during geological mapping and site inspections to identify, locate, and deliver positional and structural data. During geological mapping and field surveying, the Brunton compass will be used for navigation and physical measurements. A 50-meter measuring tape will be used to estimate the size of outcrops and river profiles. 01 'Mol' is a hydrochloric acid (HCT) solution used to detect carbonate-containing rocks like limestone. Plastic samples will be utilised to gather rock samples prior to laboratory examination. Finally, a hand lens (10x magnification) is useful for detecting minerals while documenting lithology. All of the aforementioned information may be obtained from the Earth Science Faculty of the Geoscience Department.

3.2.2 Landslide Susceptibility Mapping

A landslide susceptibility map, which ranges from low to high and highlights potentially hazardous places. The landslide susceptibility map considers slope, soil type, and the influence of water flow in a specific location when determining where landslides occur and what causes them. Geological mapping were utilised to assess the geomorphology, geological structure, stratigraphy, and lithology of rocks in the research area, resulting in primary data. Secondary data such as topographical maps, rainfall maps, and satellite images were utilised to calculate slope, aspect, land use, distance to stream, and distance to road. All necessary data were combined to create a landslide susceptibility map. Digital data were collected using the USGS, Google Earth Pro, and the Department of Drainage and Irrigation (JPS).

3.3 Method

3.3.1 Preliminary studies

The prior research should be carefully reviewed. Previous publications, journals, and other publications are necessary for a researcher to discover knowledge. To interpret and evaluate the study's objectives, landslide hazard mapping and geology, which include lithology, geomorphology, structural, previous landslides, and causes that induce landslides, require data or parameters. This may be closely related to the lithology and landform units of the area by making use of previous research and taking aerial photographs of the relevant research region. All information will be gathered from both primary and secondary sources, including data from remote sensing and on-site mapping. A topographic map could be made using satellite images. It is possible to differentiate between recent and old satellite images. Aspect is one of the main causes of landslides; we can download an aspect map from the USGS.

3.3.2 Field studies

Geological mapping will be done to look into the features of the study. Calculate the area's structural geology, lithology, weathering, and geomorphology in order to identify the factors that cause landslides. While geomorphology is discovered and a carefully chosen sample of rocks is taken for petrographic analysis, structural analysis is carried out in geological mapping by travelling along the lineament on the topographic map. Geological mapping will be used to collect primary data, and previous topographical and historical geology investigations in the study area will provide secondary data. The strike and dip of boulders or outcrops will be measured. The research site will be captured on camera. In the area affected by the landslide, significant data will be gathered using a Global Positioning System (GPS) survey. A GPS survey will be conducted in Kampung Sungai Satan, Jeli, Kelantan, using a Garmin MONTERRA with an average accuracy of 5 metres in 153 landslides that are affected by the position points. To compile all pertinent data on previous landslide operations in the area, a field study will be conducted. Additionally, it aids in the validation of different causative factor maps developed during the pre-field work. After the mapping is complete, a geological map will be produced.

3.3.3 Laboratory work

The thin section method will be used to analyse the samples and data collected at the study location in order to identify minerals and rock type. Laboratories are used to get precise data, such as the mineral that is undetectable to the human eye.

3.3.4 Data Collection and Data Processing

Geological Mapping

Geological mapping will be used to determine the geomorphology, geological structure, stratigraphy, and lithology of rocks in the research region, generating primary data by doing traverse. Secondary data such as topographical maps, rainfall maps, and satellite images will be used to compute the slope, aspect, land usage, distance to stream, and distance to road. All available data will be integrated to generate a landslide susceptibility map. In order to investigate the study area geological characteristic, the drainage pattern, joint data, strike and dip data and faulting data will also be collected. The USGS, Google Earth Pro, and the Department of Drainage and Irrigation (JPS) will all be digitally compiled.

Landslide Susceptibility Mapping

While mapping the research region, GPS (Global Positioning System) is utilised to identify the area. Using the satellite image, DEM software is utilised to produce 2D models of the research region. A map of landslide susceptibility was developed using geographic information systems (GIS). GIS may be used to construct maps of landslide susceptibility that emphasise the probable landslide zone in an intelligible way. Models may be created, updated, and managed using the ModelBuilder in Arc GIS 10.3, a visual programming language for geoprocessing workflows. It is required for the creation and execution of processes. Landslide assessment at Sungai rual, Jeli, using the Arc Map 10.3 ModelBuilder. We utilised a criterion score table based on the opinions of industry specialists to calculate Euclidean distances for each shapefile. The ModelBuilder was used to construct the final risk zoning maps for minor and major criteria using reclassification and weighted overly methods (WOM). In addition to Google Earth Pro, we used a separate programmer to create a path and get the coordinates and elevation of the region. Various criteria and qualities must be assessed before this can be performed. There are six (6) possible parameters such as lithology, slope, aspect, Land use, distance to stream and distance to road that to be overlaid in order to produce landslide susceptibility map.

3.3.5 Data analysis

All secondary data will be assessed using geological characteristics and a geographic information system (GIS) to identify landslide risk zones. Landslide susceptibility may be assessed using a variety of geological parameters and slope steepness. The degree of landslide susceptibility in vulnerable areas may be classified as low, medium, or high.

As AHP is a way for organising and analysing complex options systematically, weight will be allocated by referring to the previous study by Saaty,1980. The level of landslide susceptibility can be determined either in the low, moderate, or high potential classes of prone area. In conclusion, by using AHP, all the parameters will be analysed in terms of its weightage, then the ModelBuilder will be used to overlay all the parameters by using WOM and eventually producing the landslide susceptility map.

Petrographic analysis

Mineral components in ceramics are determined in a petrographic laboratory using petrography. Petrographic testing involves examining rock or concrete samples under a microscope to determine their mineralogical and chemical qualities. Samples for petrographic examination may be acquired from lump samples or cores. A thin section (also known as a petrographic thin section) is a laboratory preparation of a rock, mineral, soil, pottery, bone, or metal sample for use with a polarising petrographic microscope, electron microscope, or electron microprobe in optical mineralogy and petrography.

3.3.5.1 Rainfall distribution

Based on the rainfall distribution data from the climate data, it shows that the amount of rainfall distribution increased significantly compared to the previous year. Data from the month of January shows that the rainfall distribution in Jeli.

Summers are clear, and Jeli is currently experiencing one. January, February, March, April, May, June, July, August, and September have the mildest temperatures and are thus the most pleasant months to travel. November has the highest relative humidity of any month (91.37%). April is the month with the lowest relative humidity (80.49 %). When compared to other months, November has the most days with rain (26.43 days). February is the month with the fewest number of rainy days (13.73 days). Jeli experiences heavy precipitation on a yearly basis. Even in the driest month, this holds true. According to the Köppen-Geiger climate classification system, this region has an Af climate. Jeli has an average annual temperature of 24.3 °C, or 75.8 °F. Precipitation averages about 2716 millimetres (106.9 inches) per year. We see the fewest showers in February. Precipitation this month has averaged 77 mm (3.0 inches). The highest average rainfall occurs in December (338 mm | 13.3 inch).

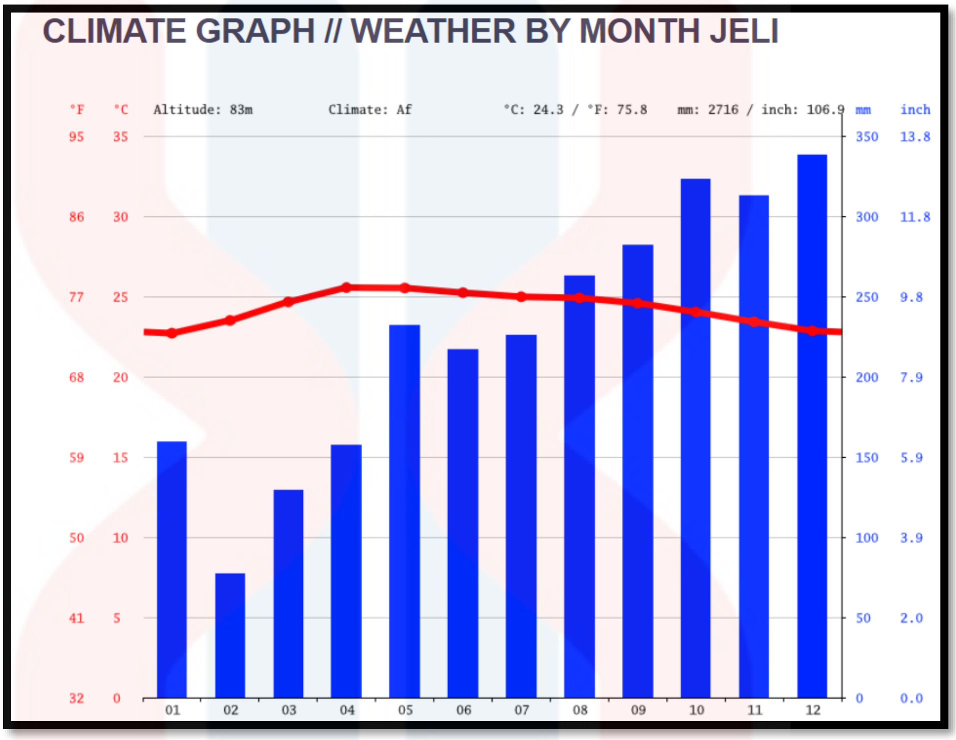


Figure 3.1 Rainfall distribution

WEATHER BY MONTH // WEATHER AVERAGES JELI

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature °C (°F)	22.7 °C (72.9) °F	23.5 °C (74.3) °F	24.7 °C (76.4) °F	25.5 °C (78) °F	25.5 °C (77.9) °F	25.2 °C (77.4) °F	25 °C (77) °F	24.9 °C (76.8) °F	24.6 °C (76.2) °F	24 °C (75.3) °F	23.4 °C (74.1) °F	22.9 °C (73.1) °F
Min. Temperature °C (°F)	20 °C (68) °F	19.9 °C (67.8) °F	20.9 °C (69.7) °F	21.9 °C (71.5) °F	22.3 °C (72.2) °F	22 °C (71.6) °F	21.6 °C (70.9) °F	21.5 °C (70.8) °F	21.5 °C (70.6) °F	21.4 °C (70.5) °F	21.1 °C (70.1) °F	20.7 °C (69.2) °F
Max. Temperature °C (°F)	26.1 °C (79.1) °F	27.8 °C (82) °F	29.5 °C (85.1) °F	30.5 °C (87) °F	30.3 °C (86.5) °F	29.9 °C (85.8) °F	29.7 °C (85.4) °F	29.7 °C (85.4) °F	29.2 °C (84.5) °F	28.2 °C (82.8) °F	27 °C (80.6) °F	26 °C (78.8) °F
Precipitation / Rainfall mm (in)	159 (6)	77 (3)	129 (5)	157 (6)	232 (9)	217 (8)	226 (8)	263 (10)	282 (11)	323 (12)	313 (12)	338 (13)
Humidity(%)	88%	83%	81%	80%	85%	86%	86%	86%	87%	90%	91%	91%
Rainy days (d)	15	10	13	15	18	18	18	18	19	20	20	18
avg. Sun hours (hours)	5.9	7.2	8.2	8.9	9.2	9.7	9.7	9.5	9.2	8.0	6.5	5.4

Table 3.1 : Average temperature and rainfall precipitation (Climate, 2021)

Research flow chart

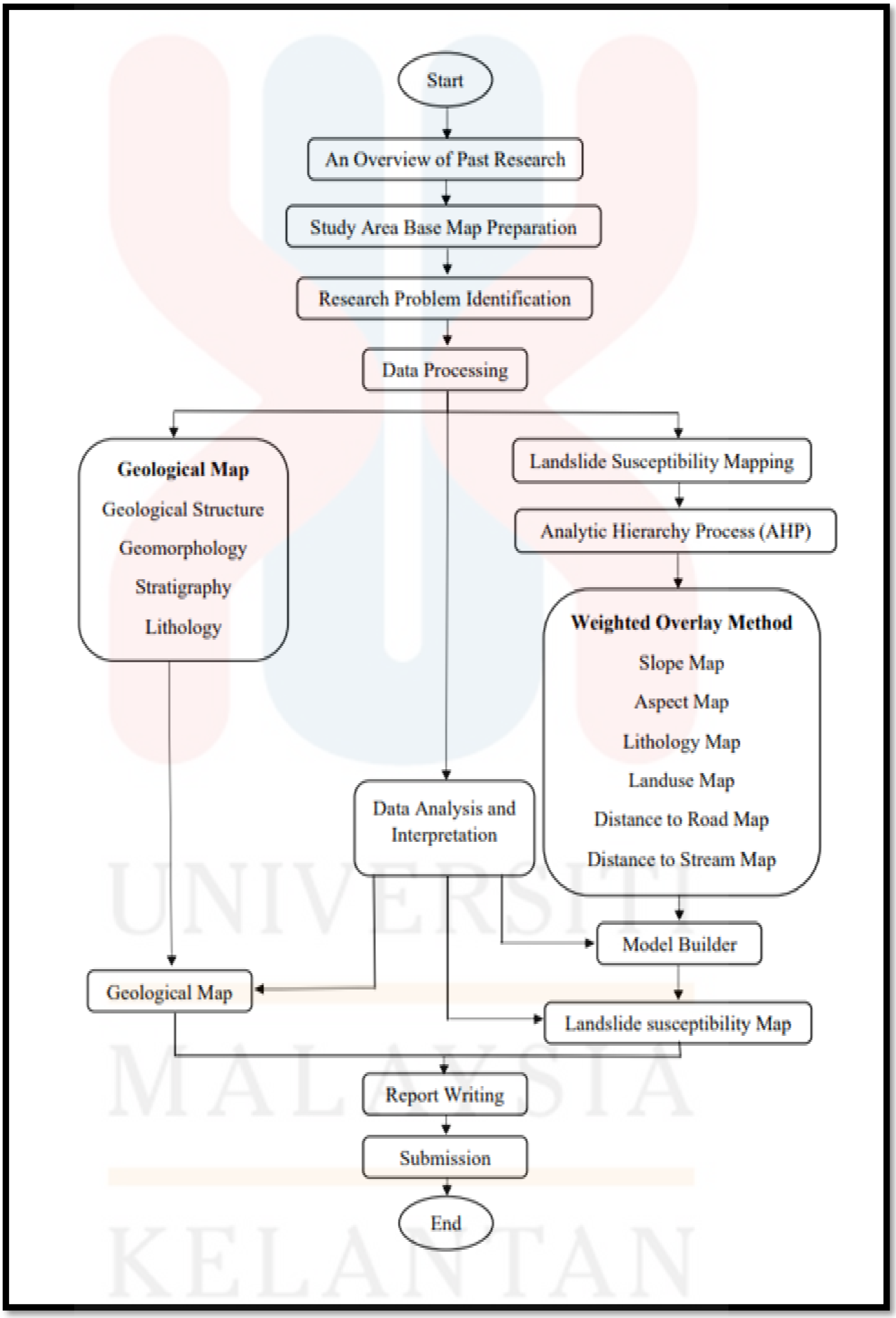


Figure 3.2: Research flowchart

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

General geology is a broad field that encompasses many aspects of the Earth and its processes. This includes the origins of the universe and solar system, the characteristics and formation of rocks and minerals, and geological processes such as the rock and hydrological cycles. The study area at Sungai Rual is characterized by a diverse landscape with varying elevations and contours, some of which are difficult to access due to their dangerous conditions. This makes studying the area challenging, as certain areas may be difficult to explore due to lack of accessibility.

4.1.1 Accessibility

In Sungai Rual, roads are the main type of connection system. There are two kinds of roads that are paved and unpaved. It is along the road that goes from Jeli town to study area is about 5 km and should take about 6 minutes and from University Malaysia Kelantan, the distance to the study area is about 10 km and should take within 11minutes to arrive. In addition, there is only one main route that connects Kampung Sungai Rual to Bandar Jeli and Jalan Lata Janggut.. This route is used by most local people and outsiders as the main link. Other than that, the unpaved road were also used during the study as a road link.

4.1.2 Settlement

The study area is located in Sungai Rual, which part of Jeli district. in the study area, there are Malay villages as soon as you enter the study area and then there are several aboriginal villages. Both are on the left side of the study area through the main road from Jeli town. This village has a primary school, Sekolah Kebangsaan Penderas. The name of this village is in conjunction with the Rual River that flows through this village and flows into the Pergau River. Around the year 1972 which at that time there were 7 aboriginal people. The area of the Orang Asli village in Kampung Sungai Rual is 659 hectares. The Orang Asli who live in this village are from the Jahai ethnic group. A total of 516 indigenous people living in this village are Muslims.

4.1.3 Forestry (or vegetation)

Within Sungai Rual region, vegetation covers about 80% of the area in the study area. It is a region of high land, consisting hill to high hill which is very limited to access. With its highest elevation, 800 m, it is where the highest hill in the study area. The Sungai Rual area consist of small amount agriculture activities such as rubber plantation and the area majority consist of hill to high hill forest where the area have very limited accessibility.

4.2 Geomorphology

Geomorphology is the scientific study of the physical characteristics and formation of the earth's surface. This includes the shape and geometry of the terrain, as well as the processes that shape it, both external and internal. In order to understand the changes that occur on the earth's surface in a specific area, it is important to study the geomorphological processes that are active in that area. This knowledge is crucial in understanding how the landform has been shaped over time, and how it may change in the future.

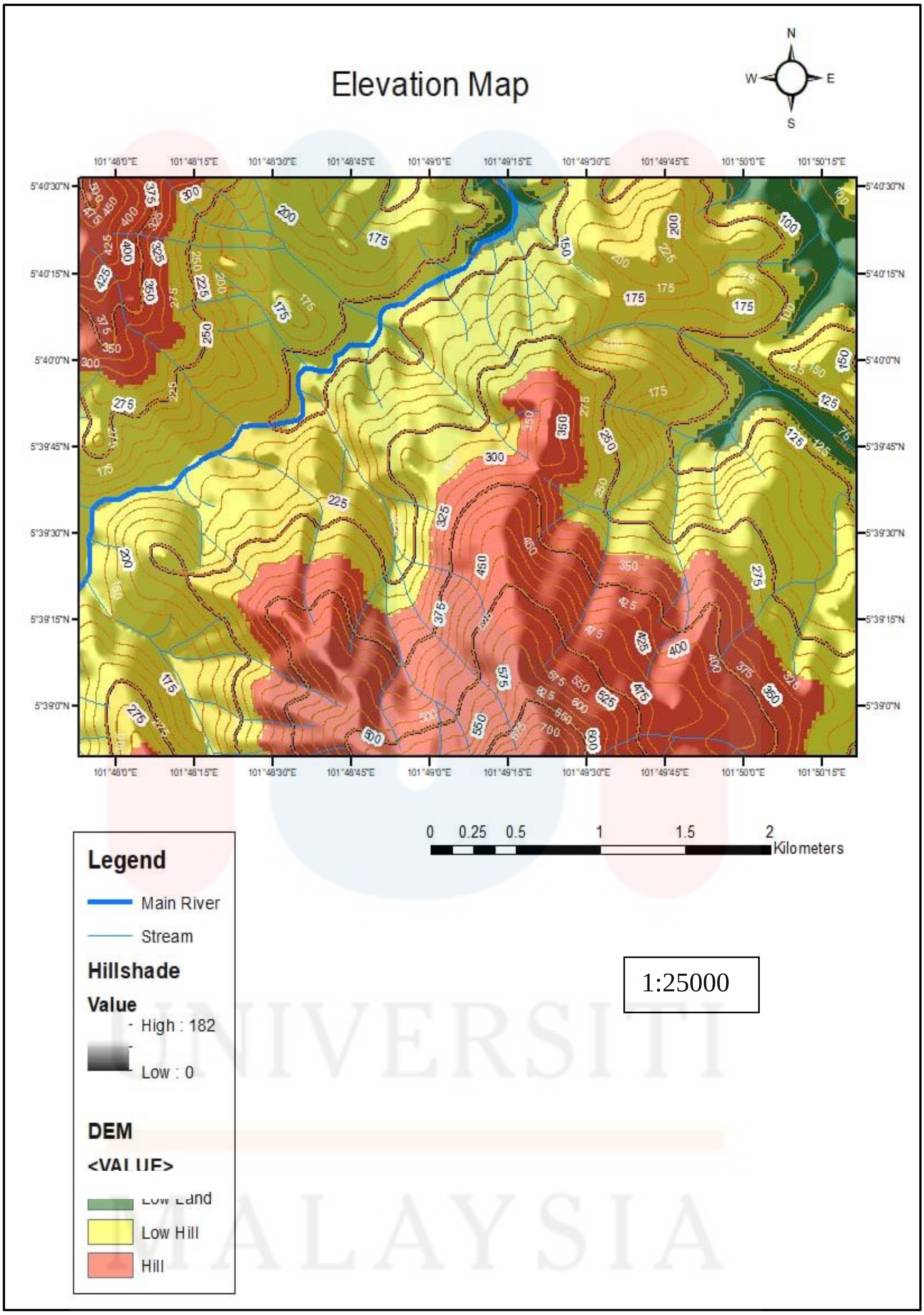


Figure 4.1 The elevation map of the study area

4.2.1 Topography

Topography refers to the features that make up the surface of the Earth, including landforms, elevations, and relief. It is measured by the differences in elevation across the surface of the Earth, and is categorized into five different classes based on elevation. These classes are known as topographic units, and they are further broken down into their individual components. The information about these units is often presented in a table, such as Table 4.1, for easy reference and summary.

Table 4.1 Landform (Van Zuidam, 1985)

Landform	
5 m – 100 m	Low lying plain
100 m – 200 m	Low hills
200 m – 500 m	Hills

4.2.2 Weathering

Weathering is an essential geological process that occurs when rocks and minerals are exposed to the atmosphere. It involves the alteration and breakdown of rock materials in place, without the need for significant movement. There are three main types of weathering: physical, chemical, and biological. Physical weathering is caused by changes in temperature and minerals, which can lead to the mechanical disruption of rocks. Chemical weathering involves the decomposition of rock-forming minerals due to the presence of water, temperature, oxygen, hydrogen, and mild acids. Biological weathering is the result of the actions of living organisms such as plants, animals, and microorganisms, which can cause the disintegration of rocks over time. Together, these weathering processes shape and sculpt the Earth's surface, creating unique landscapes and geologic features.

In this study area of Kg Sungai Rual, Figure 4.2 showed the physical and biological weathering occurred. The big scale outcrop undergoes the disintegration of rock resulted the smaller sizes of rocks presented also the green plants are started to cover the rock. It was hill-typed outcrop and highly weathered as the properties of rocks and minerals were hardly observed due to changing colors of minerals.

As for the Figure 4.3 showed only the biological weathering happened to the outcrop. Small trees and herbs has habitat there greenly as the roots were penetrated into the fractures of rocks thus covered the rock slopes along the roadside of East-West highway. Reptiles such as lizard and insects for example cockroach also lived there as their protected habitat in the small space of rock’s fractures.

Figure 4.2 Physical and biological weathering occur on the outcrop

Figure 4.3 Biological weathering occur on the outcrop

4.2.3 Drainage Pattern

The drainage system refers to the pattern of rivers, streams, and lakes that develop within a specific drainage basin. This pattern is influenced by a number of factors, including the type and distribution of rock, as well as the location of that rock on the surface. The drainage pattern is typically shaped by the arrangement of weaknesses in the rock, such as bedding planes, faults, and joints. Other factors such as folding, rainfall, and erosion can also play a role in shaping the drainage system. The hills and basins surrounding a study area are an important part of the drainage system, as they channel the flow of water into rivers and streams in the area. Drainage system is an important aspect of geomorphology, as it can have a significant impact on the landscape and natural resources of a region.

The map in Figure 4.4 shows that the dendritic drainage pattern is the dominant pattern in the study area. This pattern is characterized by a branching structure, resembling the roots of a tree. It typically forms when the river's channel follows the terrain slope, allowing the downhill stream to flow in the same direction as the uphill stream and eventually meet in a larger or main stream. Dendritic patterns are common in areas where the rock is relatively uniform and permeable, and the slope is gentle. Dendritic drainage pattern is the most common drainage pattern on the Earth's surface and is an important aspect of the geomorphology of a region because it can have a significant impact on the landscape and natural resources.

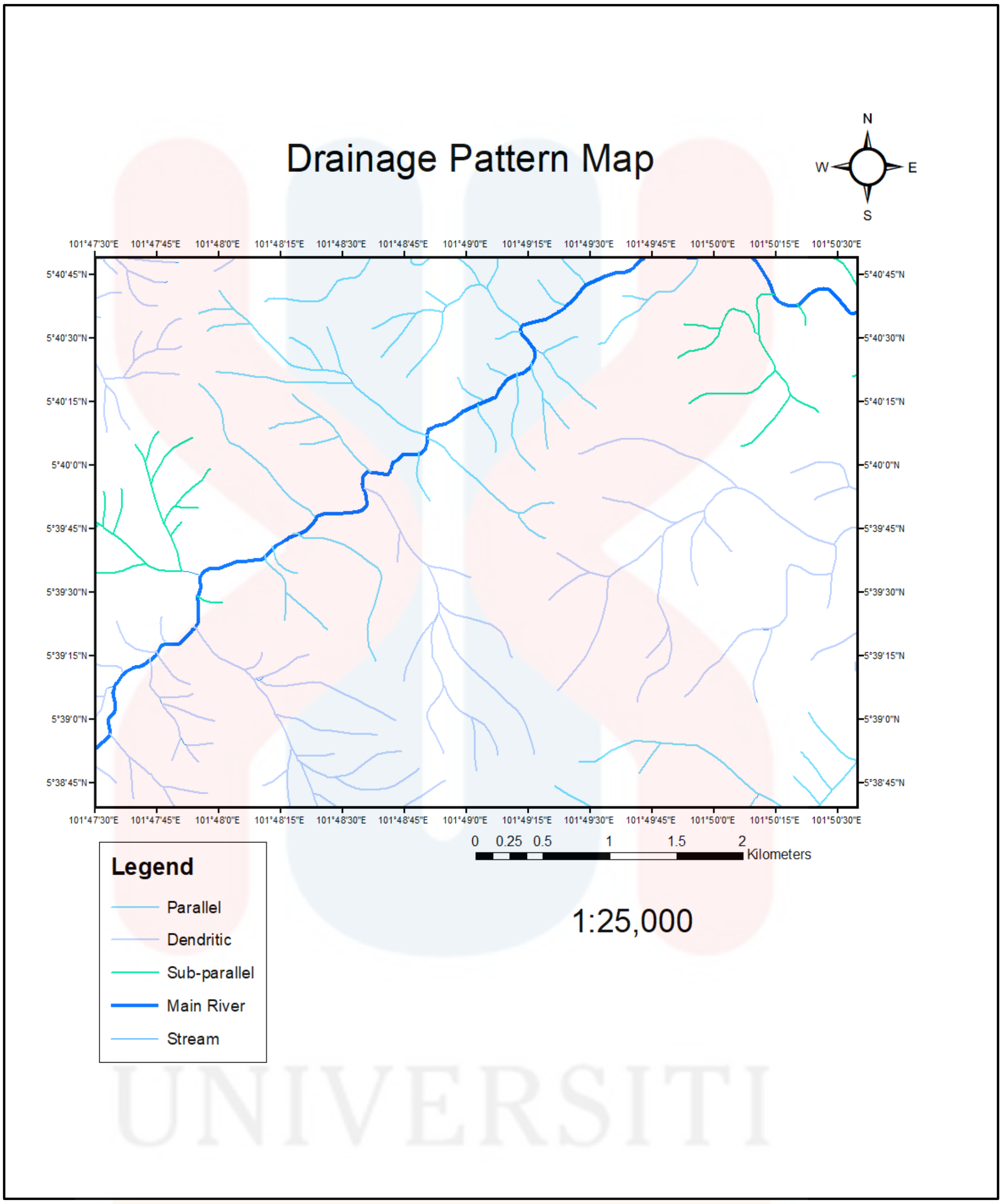


Figure 4.4 The drainage pattern map of study area

4.3 Lithostratigraphy

Lithostratigraphy is a sub-discipline of stratigraphy, which is the geological science of studying strata or rock layers. Major research areas include geochronology, comparative geology, and petrology. In general, the strata relating to the formation of the rock are either igneous or sedimentary. The layer that is first deposited and then intruded will later describe the age of the rocks. The oldest rock in this area of study is Ordovician-Silurian-age gneiss and schist, while the youngest rock is Tertiary-age granite. Based on Table 4.2, the lithostratigraphy depicts the lithology of the rocks that existed in Sungai Rual.

Based on the geological map in Figure 4.5 in Sungai Rual, it can be concluded that igneous rocks, specifically granite, cover approximately 70% of the area. Metamorphic rock, such as schist and gneiss, covers approximately 30% of the study area. This information was gathered from geological mapping in the study area and interpreted in a map created with ArcGIS.

Table 4.2 Lithostratigraphy column in Sungai Rual

STRATIGRAPHY

STRATIGRAPHY COLUMN

LITHOLOGY	DESCRIPTION	UNIT	PERIOD	ERA
	The main feature of this unit is quartz and followed by alkali feldspar	Granite	Tertiary	Cenozoic
	Mainly consist of gneiss, schist and granite	Gneiss	Palaeozoic	Ordovician-Silurian
	Mainly consist of schist and granite	Schist	Palaeozoic	Ordovician-Silurian

LITHOLOGY COLUMN

LITHOLOGY	DESCRIPTION
	Kampung Sungai Rual granite rock have massive structure, faneric texture and coarse - medium grain size. It also consist of quartz 69%, Alkali feldspar 30% and 1% of opaque minerals.
	In the study area, Gneiss have foliated structure, crystalloblastic texture including grain size <1/16 - 1 mm and poor sorted. The minerals composition were Feldspar 35%, Quartz 25%, Biotite 35% and opaque minerals 5%.
	Schist composition in the area consist of 78% quartz, biotite 15%, feldspar 6% and opaque minerals 1%.The grain size <1/16 – 1/2 mm, and good sorting.

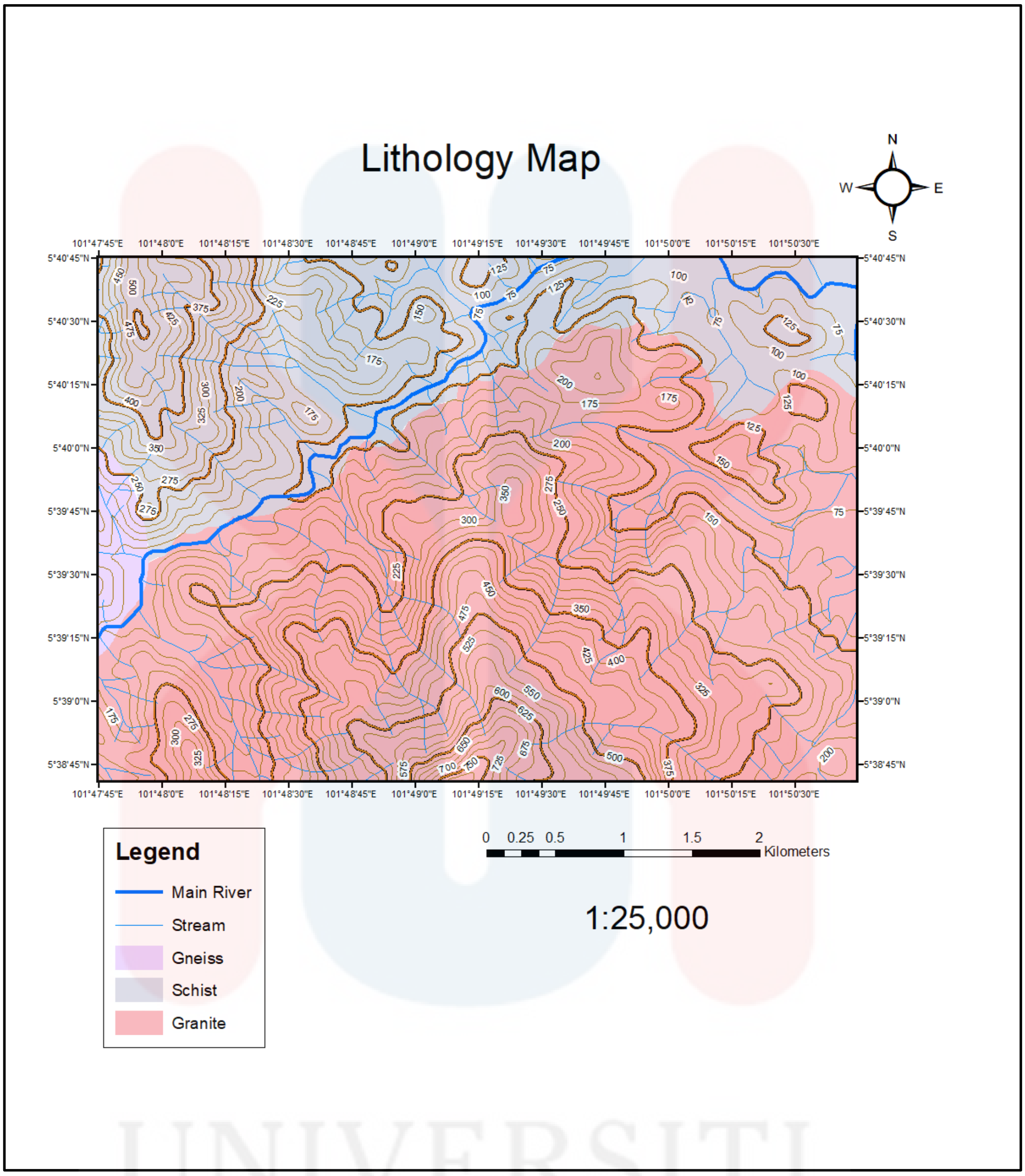


Figure 4.5 Lithology map of Sungai Rual, Kelantan

4.3.1 Unit Explanation

a) Granite

Granite is a type of igneous rock formed underground by the cooling and solidification of magma with high concentrations of quartz, alkali feldspar, and plagioclase. It has a coarse-grained texture and can be found in various sizes, from small dikes to large batholiths, in the continental crust. It may also contain mica or amphibole minerals, with the exception of a specific type called leucogranites which do not have any dark minerals.

Figure 4.6: The granite outcrop of Kampung Sungai Rual

Figure 4.7: The hand specimen of granite

b) Schist

Schist is a type of metamorphic rock that is recognized by its medium-sized grains, visible under low magnification, that are arranged in a manner that allows the rock to be easily split into thin flakes or plates. The rock is composed of a mixture of platy minerals such as micas, talc, chlorite, and graphite, which give it this distinct texture. These minerals are often found in combination with coarser minerals like feldspar or quartz. Schist is formed through regional metamorphism that occurs during mountain building, and it is a representation of moderate metamorphism. Schist can be formed from a variety of rocks, including sedimentary rocks like mudstones and volcanic rocks like tuffs.

Figure 4.8: The schist outcrop of Kampung Sungai Rual

Figure 4.9: The hand specimen of schist

c) Gneiss

Gneiss is a prevalent and extensively distributed metamorphic rock formed through the alteration of igneous or sedimentary rock under high temperatures and pressures. It is formed at higher temperatures and pressures compared to schist. Gneiss is characterized by its banded structure, with alternating bands of darker and lighter colours and no clear cleavage.

Figure 4.10: The hand specimen of gneiss

4.3.2 Petrographic Analysis

This section includes a petrography analysis of the rock based on macroscopic and microscopic properties. Petrographic analysis reveals a rock's origin, whether igneous, sedimentary, or metamorphic, as well as its mineral content, in order to classify it. The description of macroscopic aspects of the rock, such as texture, colour, grain size, and other relevant characteristics visible in hand specimens or outcrops, is typical, as is the identification and description of microscopic characteristics of the studied material in thin sections, such as mineral composition, texture, grain size, and evidence of alteration and/or deformation.

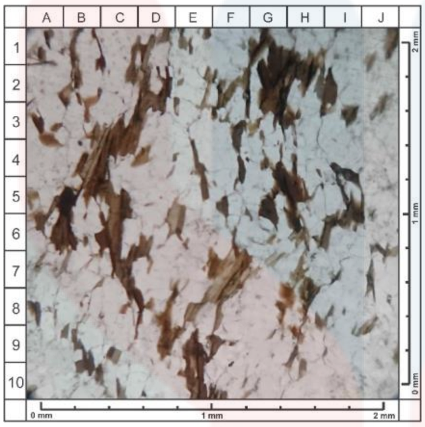
Based on the data acquired, two types of rock were discovered in the area which are igneous and metamorphic rock. The sample identified for igneous rock is granite rock, which is the main type of rock in the study area, accounting for around 70% of the total. Schist and gneiss are the metamorphic rock samples, and each only covers about 30% of the research region. The petrography analysis results are shown in tables 4.3, 4.4, and 4.5 to characterise the mineral composition in each rock type in further detail.

Table 4.3: Petrographic analysis result for schist

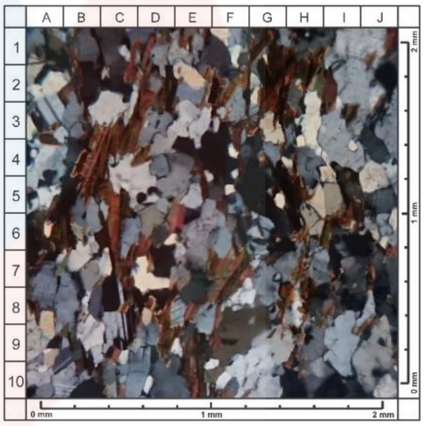
PETROGRAPHY ANALYSIS RESULT

SAMPLE CODE: ADEEL

PPL (Plane Polarized Light)



XPL (Cross Polarized Light)



Microscopic analysis:

The observations were carried out at 10x ocular magnification and 5x objective magnification and at the observation of foliation structure (schistose), crystaloblastic texture (nematoblastic) including grain size <1/1 6 – 1/2 mm, sorting well.

Mineral Composition:

Quartz (J10) – 78%

In PPL color absorption is colorless, relief is low, pleocroism is absent, anhedral crystalline forms, hemispheres are absent. In XPL the color of the gray – white interference of the 1st order, the dark corners are wavy, twins are absent.

Biotite (C4) – 15%

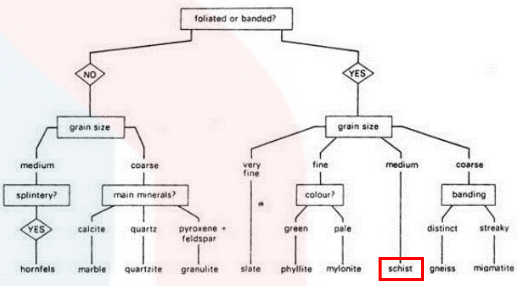
In PPL the absorbtion color is brown – greenish, medium relief, strong pleochroism, subhedral crystalline form – euhedral, hemisphere 1 direction. In XPL the interference color is green – orange of the 3rd order, the dark corners of the twin parallels are absent.

Feldspar (B10) – 6%

In PPL color absorption is colorless, low relief, pleochroism is absent, euhedral crystalline form – anhedral, hemisphere 1 direction. In XPL the color of the interference is gray – white of the 1st order, the dark angle is parallel.

Mineral Opak (B5) – 1%

In PPL black absorption color, low relief, pleochroism is absent, euhedral crystalline form – anhedral. In XPL the color of black interference of the 1st order, twins are absent.



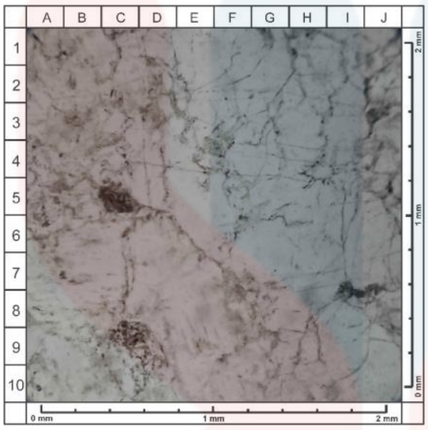
ROCK NAME: SCHIST (GILLEN, 1982)

Table 4.4: Petrographic analysis result for granite

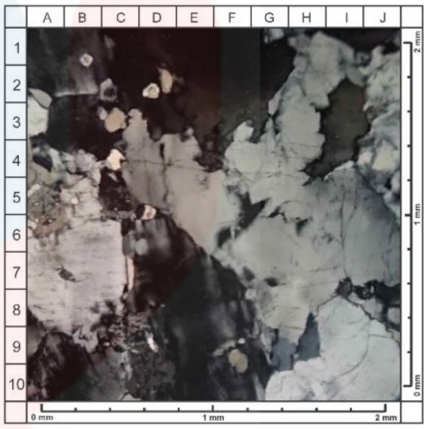
PETROGRAPHY ANALYSIS RESULT

SAMPLE CODE: ADEEL

PPL (Plane Polarized Light)



XPL (Cross Polarized Light)



Microscopic Analysis:

At such observations were made at an ocular magnification of 10x and an objective magnification of 5xand on the observation of massive structure, fanertexture, coarse - medium mineral size.

Mineral Composition:

Quartz (J10) – 69%

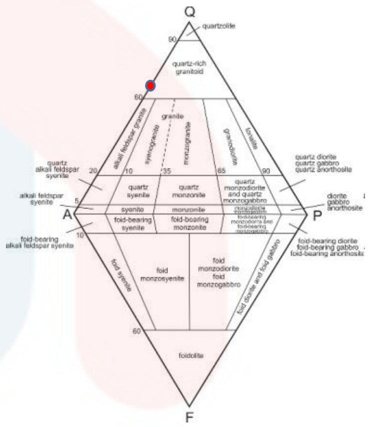
In PPL color absorption is colorless, relief is low, pleocroism is absent, anhedral crystalline forms, hemispheres are absent. In XPL the color of the gray – white interference of the 1st order, the dark corners are wavy, twins are absent.

Anortoklas (A7) – 30%

In PPL color absorption is colorless, relief is low, pleochroism is absent, anhedral crystalline form, hemispheres 1 direction. In XPL the color of interference gray – white of the 1st order, the angle of darkness parallel – oblique, the polysynthetic twin

Mineral Opak (J3) – 1%

In PPL black absorbtion color, low relief, pleocroism is absent, euhedral crystalline form – anhedral. In XPL the color of black interference of the 1st order, twins are absent.



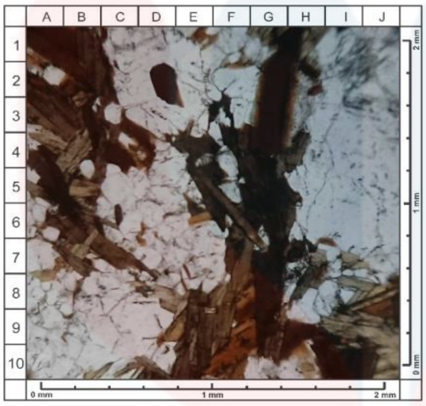
ROCK NAME: GRANITE (STRECKEISEN, 1976)

Table 4.5: Petrographic analysis result for gneiss

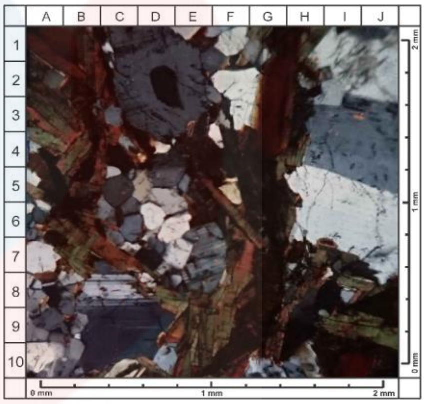
PETROGRAPHY ANALYSIS RESULT

SAMPLE CODE: **ADEEL**

PPL (Plane Polarized Light)



XPL (Cross Polarized Light)



Microscopic Analysis:

The observations were made at 10x ocular magnification and 5x objective magnification and at the observation of foliation structure (gneissic), crystaloblastic texture (porfiroblastic) includes grain size <1/1 6 - 1 mm, sorting buruk.

Mineral Composition:

Feldspar (J4) – 35%

In PPL color absorption is colorless, low relief, pleocroism is absent, euhedral crystalline form – anhedral, hemisphere 1 direction. In XPL the color of the interference is gray – white of the 1st order, the dark angle is parallel, the twin albit – kalsbad – calsbad-albit – polysynthetic.

Quartz (D5) – 25%

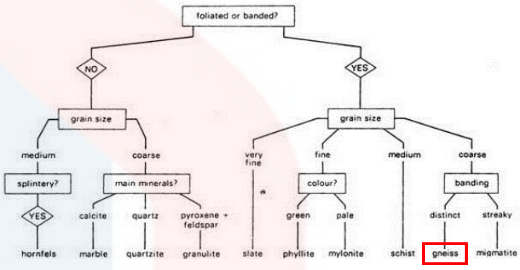
In PPL color absorption is colorless, relief is low, pleocroism is absent, anhedral crystalline forms, hemispheres are absent. In XPL the color of the gray – white interference of the 1st order, the dark corners are wavy, twins are absent.

Biotite (A1) – 35%

In PPL the absorbtion color is brown – greenish, medium relief, strong pleochroism, subhedral crystalline form – euhedral, hemisphere 1 direction. In XPL the interference color is green – orange of the 3rd order, the dark corners of the twin parallels are absent.

Mineral Opak (D2) – 5%

In PPL black absorbtion color, low relief, pleocroism is absent, euhedral crystalline form – anhedral. In XPL the color of black interference of the 1st order, twins are absent.



ROCK NAME: GNEISS (GILLEN, 1982)

4.4 Structural Geology

Primary structures were formed during the formation of rock masses, whereas secondary structures were formed as a result of primary structure deformations caused by plate tectonic movement. Structural geology is the study of the three-dimensional distribution of rock units in terms of their deformation histories. It also includes the processes that lead to the formation of geological structures and how these structures affect the rocks. The structural geology involved in this study includes structures such as lineaments and fault lines that can be interpreted using processed satellite imagery.

4.4.1 Fault

Faulting is the process by which movement in the Earth's crust causes rocks to fracture. These movements are primarily responsible for causing earthquakes. The movement in the Earth's crust can cause stress to build up over time before it is suddenly released in an earthquake. There are three types of faults: normal faults, thrust faults, and strike-slip faults. A normal fault occurs when the downthrown block moves towards the oldest rock above, while a thrust fault happens when the break occurs above the youngest rocks, affecting the oldest rocks. A strike-slip fault is when the break occurs along the vertical or horizontal plane of the fault. In some cases, the type of rock present can indicate which type of fault occurred. (Britannica, 2020).

The fault can be easily identified by lineament on the map. Aside from that, contour and rock boundary can be indicators in fault observation, as the definition of fault is a planar fracture.

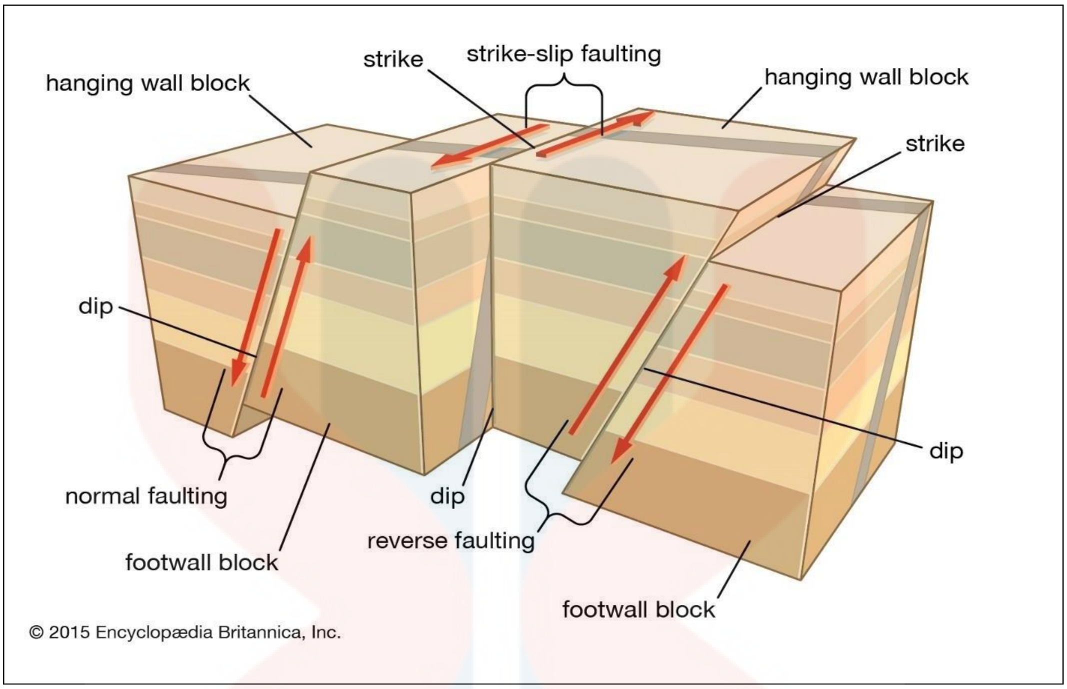


Figure 4.11 Type of fault (source: Britannica, 2020)

4. 4.2Mechanism of structure

A) Lineament analysis

There are two types of lineaments extracted, positive lineament and negative lineaments. Positive lineaments are described as the bedding which can be identified as ridge or ranges, whereas, negative lineament are described as fault or fractures which can be identified through valleys or rivers. The rose diagram was used to determine the direction, fault, force, and joint for both positive and negative lineament. Lineament was calculated in the rose diagram for analysis. (Ibrahim Komoo, 1989).

i) Analysis of Positive Lineaments

As a direct consequence of this, the rose diagram is plotted in Figure 4.9, and the positive lineament on the ridge analysis is shown in Figure 4.7. According to the rose diagram, the tension that was caused by the ridge originated is in the North-west and the South-east.

ii) Analysis of Negative Lineaments

As a result, the negative lineament on the ridge analysis shown in Figure 4.8 and the rose diagram shown in Figure 4.10 have been plotted. According to the rose diagram, the primary shear should be applied to the left because the direction the major force came from the north-west.

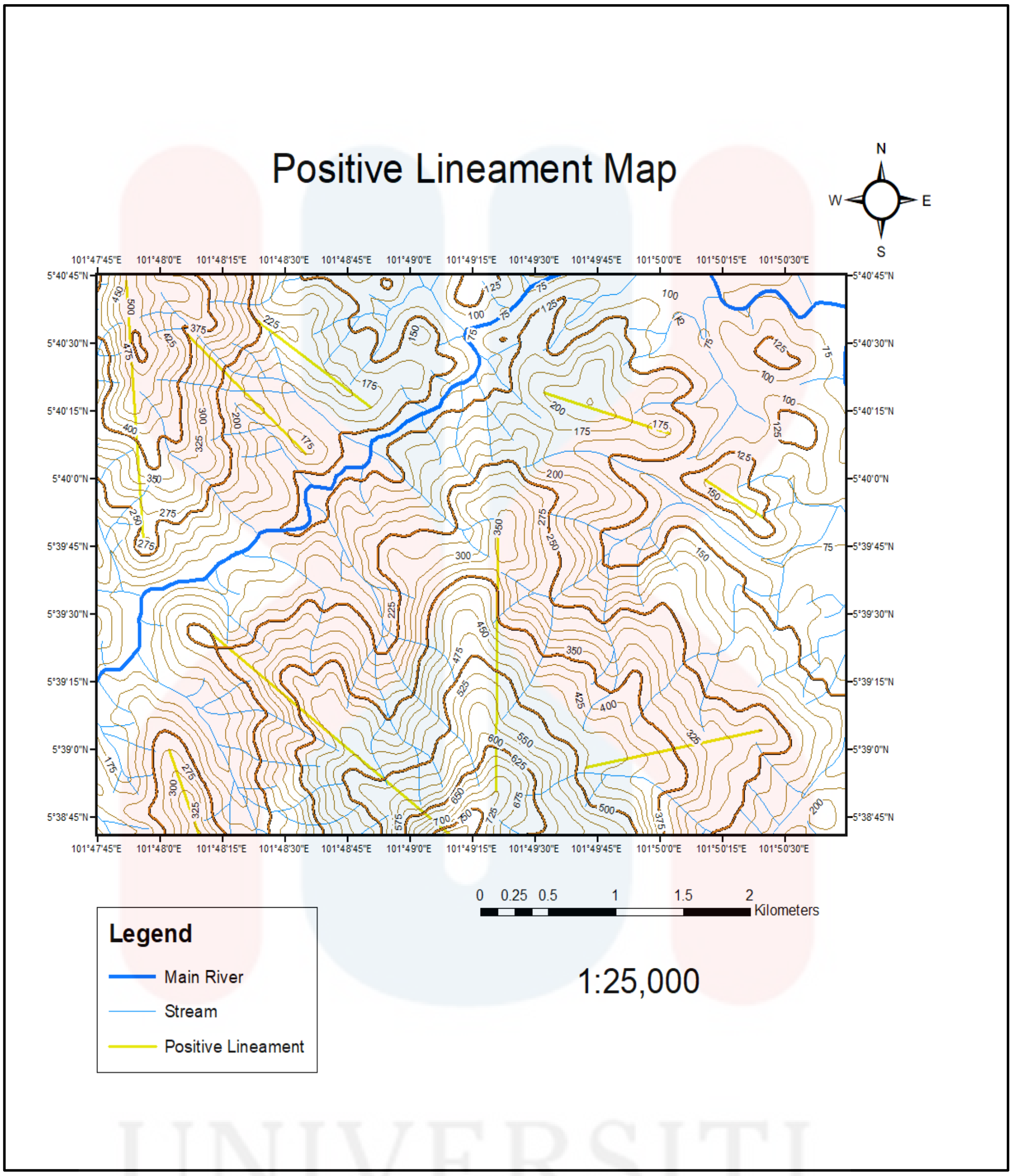


Figure 4.12 Positive lineament map

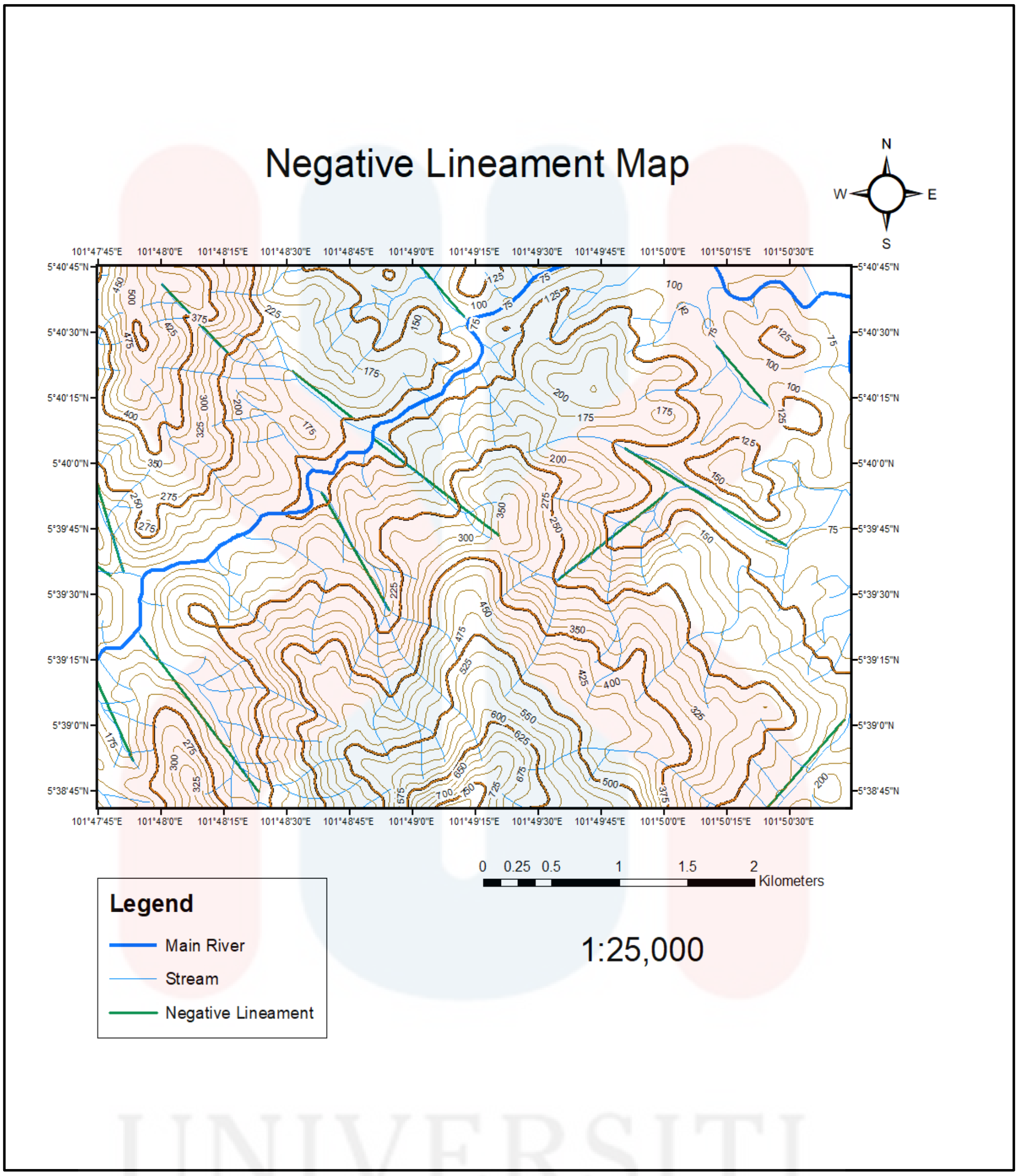


Figure 4.13 Negative lineament map

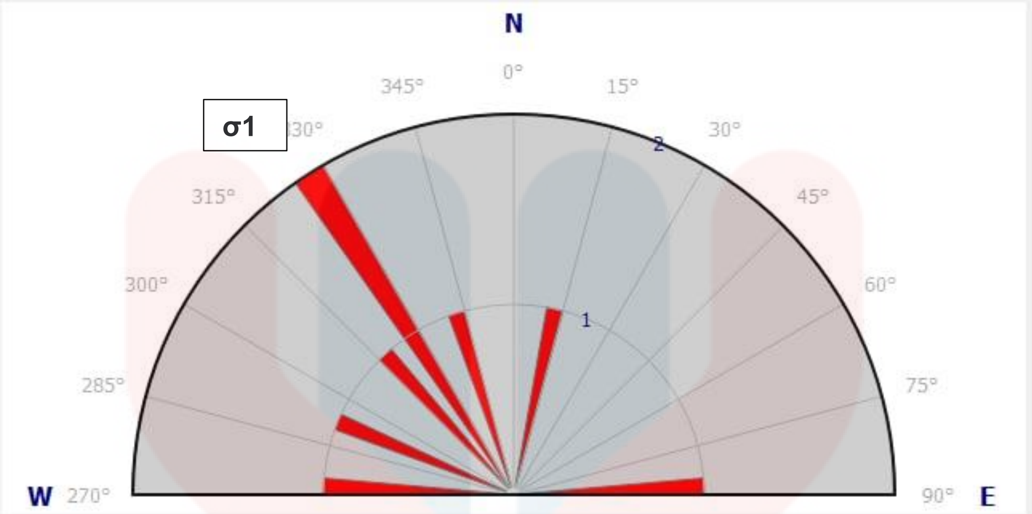


Figure 4.14 Rose diagram of positive lineament

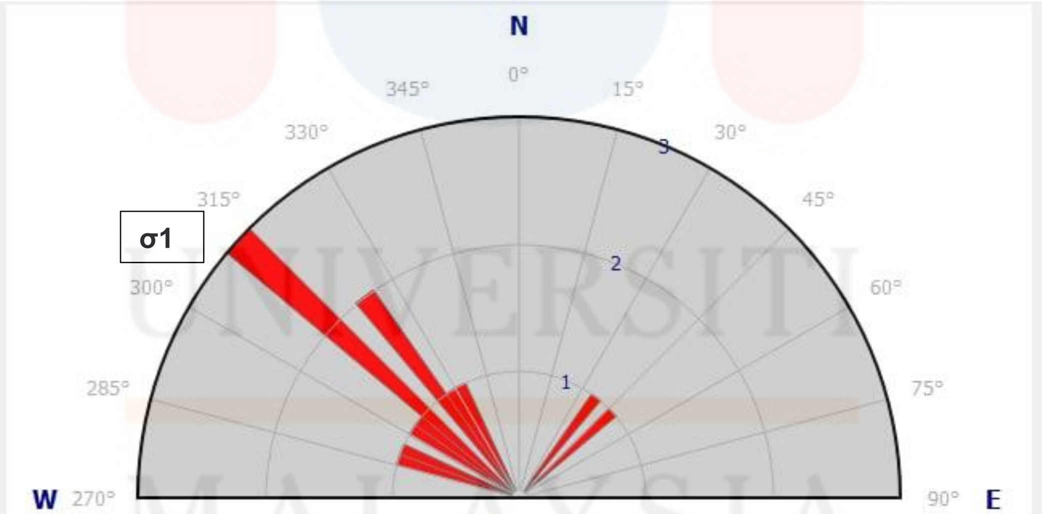


Figure 4.15 Rose diagram of negative lineament

4.4.3 Joint Analysis

The shear joint data analysis by using the rose diagram shown in Figure 4.16 have been plotted. According to the rose diagram, the primary shear should be applied to the right because the direction the major force came from the north-East.

Besides, the extensional joint data analysis by using rose diagram shown in Figure 4.17 have been plotted. According to the rose diagram, the tension that was caused by the ridge originated is in the North-west and the South-east.

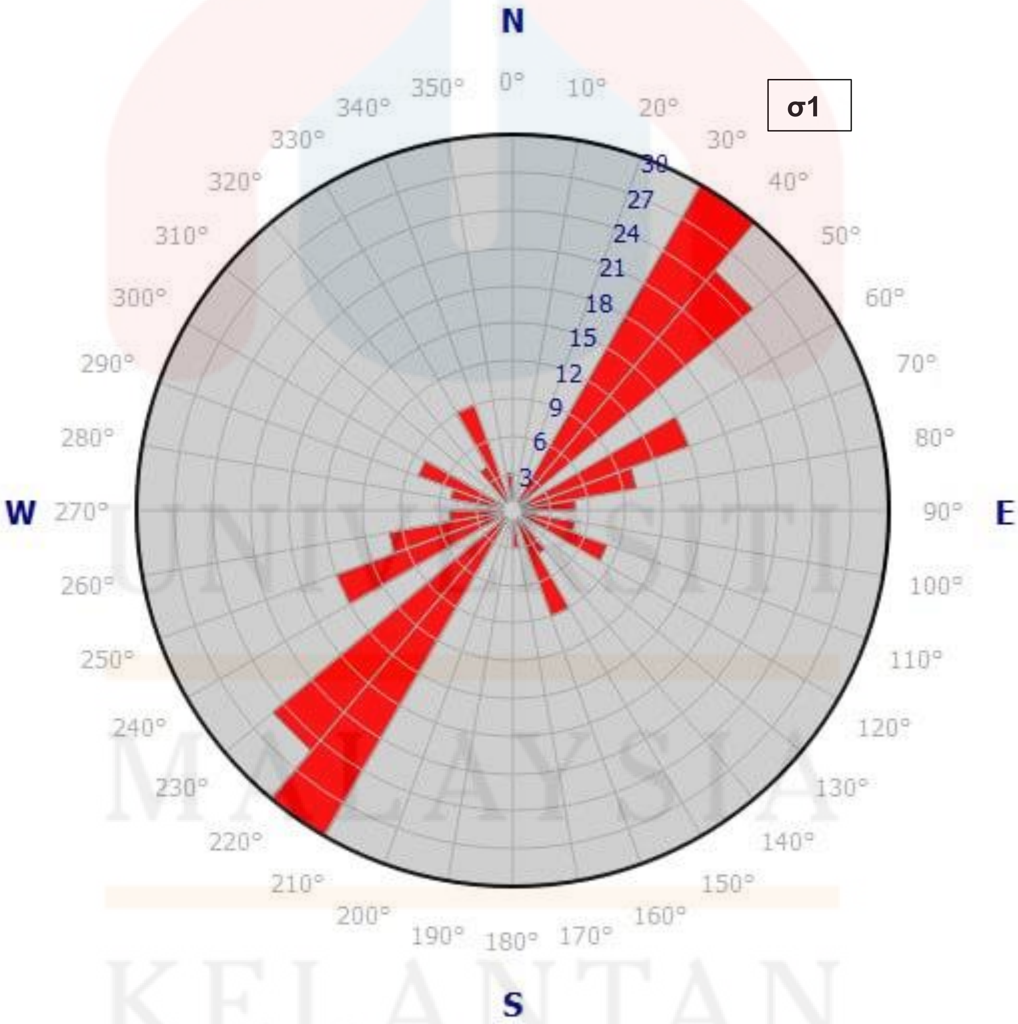


Figure 4.16: The shear joint data presented in rose diagram.

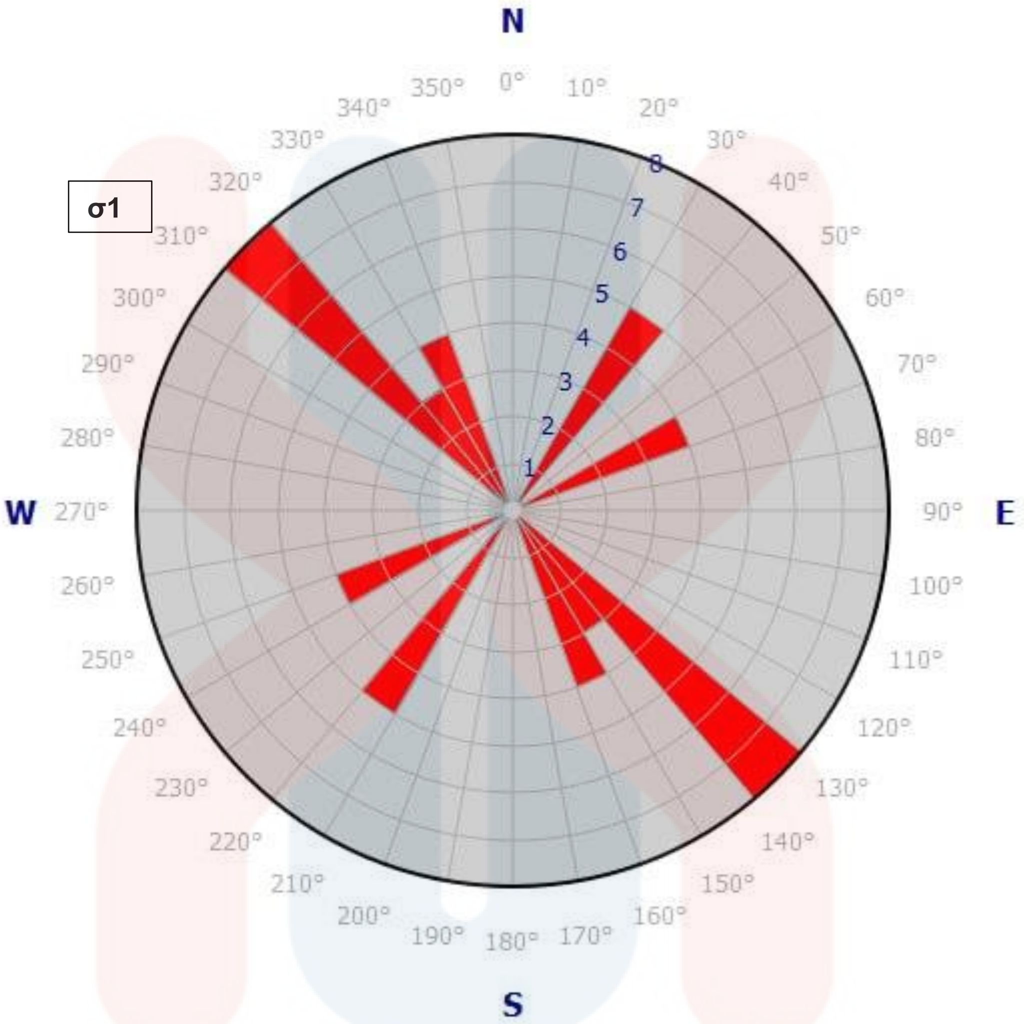


Figure 4.17: The extensional joint data presented in rose diagram.

4.5 Historical Geology

Kampung Sungai Rual is an area in which metamorphic and igneous rocks are present, including granite, schist, and gneiss. These rocks were formed through a combination of geological processes that occurred over an extended period of time.

The oldest rocks in the area are schist and gneiss, which date back to the Ordovician-Silurian era, approximately 485-419 million years ago. These rocks were formed through metamorphism, a process that involves changes in the mineralogy, texture, and structure of existing rocks due to heat and pressure. The specific conditions that lead to metamorphism can vary, but in general, it occurs at depths within the Earth's crust where these conditions are present.

At some point after the formation of the schist and gneiss rocks, igneous activity occurred in the area. Magma intruded into the existing rocks and cooled to form granite, which is the youngest rock in the area. This igneous activity occurred during the Cenozoic era, which began around 66 million years ago and continues to the present day. The specific characteristics of the resulting rock depend on factors such as the chemical composition of the magma, the rate of cooling, and the location of the magma intrusion.

Throughout the history of Kampung Sungai Rual, these geological processes have shaped the landscape and created the rocks that are present today. Erosion and weathering have exposed these rocks to the surface, where they can be observed and studied by geologists and other scientists. Overall, the geology of Kampung Sungai Rual provides insight into the complex and dynamic processes that have shaped the Earth's surface over millions of years.

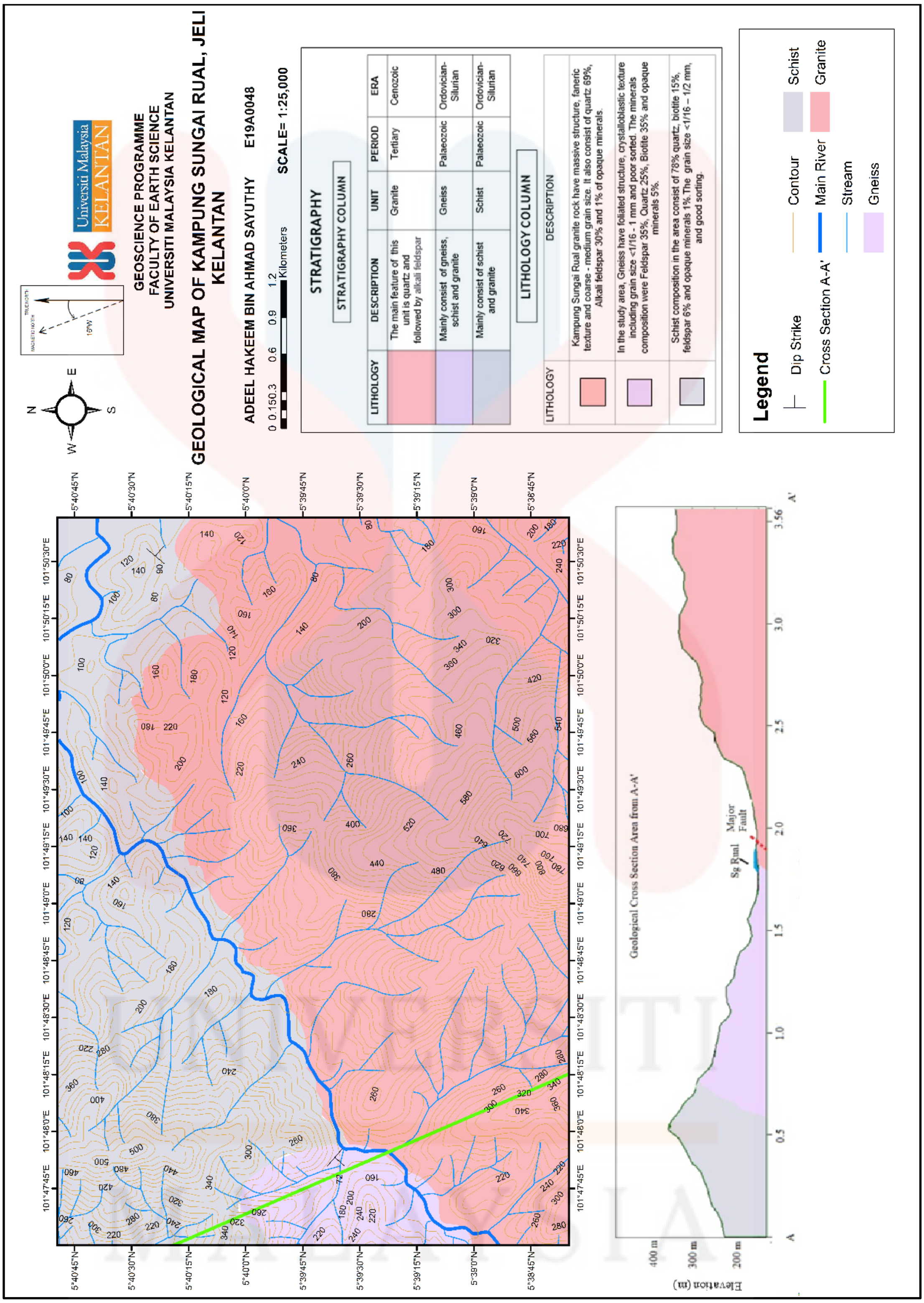


Figure 4.18: Geological map of Kampung Sungai Rual, Jeli

CHAPTER 5

LANDSLIDE SUSCEPTIBILITY MAPPING

5.1 Introduction

The study specification for this chapter will be landslide susceptibility mapping in the study area of Sungai Rual, Jeli. There are six landslide parameters or causative factors that can be used to determine the landslide susceptibility area were distance to stream, distance to road, lithology, slope, aspect, and land use. The parameters will be overlaid using the Weighted Overlay Method (WOM), in which each parameter will be assigned a weightage score and will be overlaid using ArcMap tools. Table 5.1 shows the weightage distribution for parameters. Thus, the final map created was the Landslide Susceptibility Map using WOM data processed by Model Builder in ArcGIS. This final map will depict the possibility of a landslide-prone area.

Table 5.1: The weightage distribution for parameters.

No.	Parameters	Weightage (Wi)
1.	Distance to Stream	5
2.	Distance to Road	6
3.	Lithology	7
4.	Slope	10
5.	Aspect	8
6.	Land use	6

5.2 Landslide susceptibility assessment

Due to the pressing need for mapping slope instability, various attempts have been made to classify slope stability factors using both direct and indirect methods. Direct methods, such as geomorphological mapping, and indirect methods, such as heuristic and statistical methods, are commonly used (Shahabi & Hashim, 2015). In this study, ArcGIS software was utilized to create a landslide susceptibility map, using the weighted overlay method (WOM) in ModelBuilder. The weight assigned to each parameter was determined by referencing the Analytical Hierarchy Process (AHP) analysis from a previous study by Saaty, 1980, which ensures that the weight reflects the importance of each parameter in the occurrence of landslides.

The susceptibility map was separated into three hazard levels: low, moderate, and high. The specific category of landslide was determined by its parameters. The map was constructed in ArcGIS by layering maps of all parameters. A statistical approach was then employed during the data analysis phase to identify the potential area and percentage of landslides.

5.2.1 Distance to road

One of the factors considered in the Landslide Susceptibility Map is the proximity to roads. Road construction on slopes alters both the topography and the base of the slope, which can lead to high stresses that can cause cracking. This parameter is important because the study area has a high number of landslides near roads. The results show that a value of 0m - 300m close to a landslide zone or prone zone.

Table 5.2: Distance to road

Distance to road (m)	Value
0 – 300	Near
300 – 600	
600 – 900	Moderate
900 – 1200	
1200 – 1500	Far
1500 – 1800	

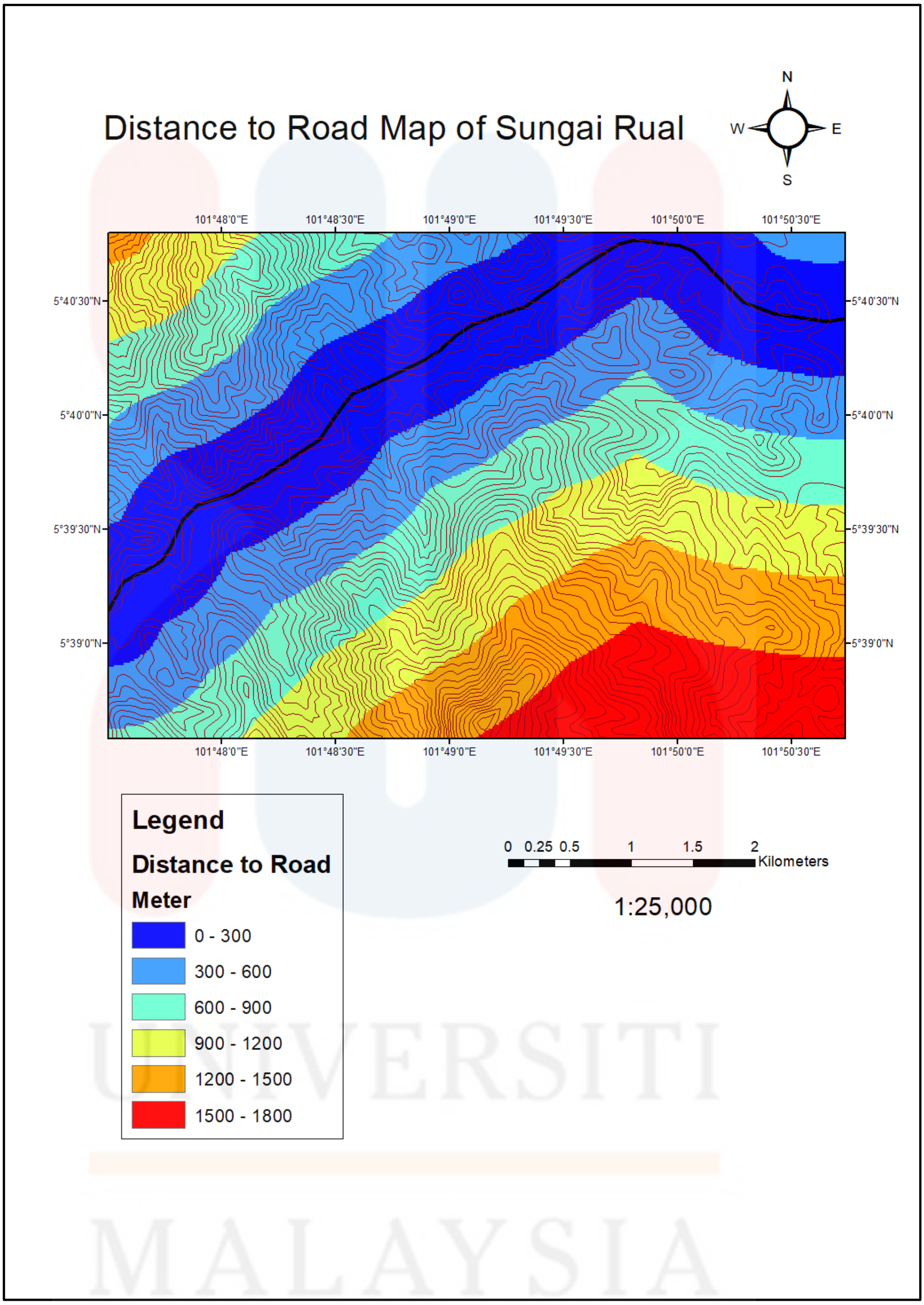


Figure 5.1: Distance to road map of study area

5.2.2 Distance to stream

The proximity of the slope to drainage structures is an additional factor that plays a significant role in determining its stability. Because they erode the slope base and saturate the underwater portion of the material that forms the slope, rivers that are part of drainage networks have a negative impact on the likelihood of landslides occurring (Pradhan & Lee, 2010). The conclusion can be drawn from the table regarding the amount of distance to the stream.

Table 5.3: Distance to stream

Distance to stream (m)	Value
0 – 200	Near
200 – 300	
300 – 400	Moderate
400 – 500	
500 – 600	Far
600 – 700	

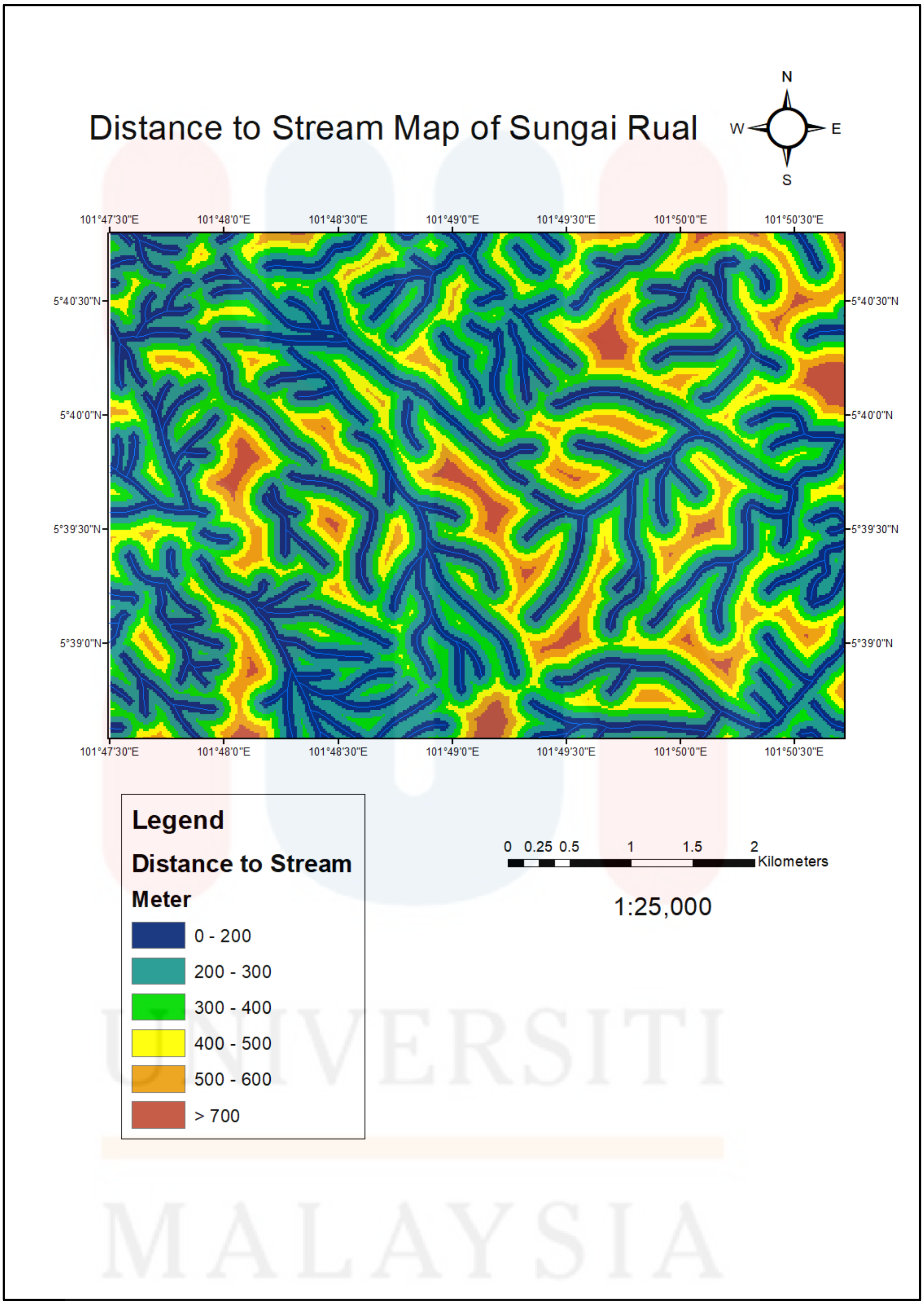


Figure 5.2: Distance to stream map of study area

5.2.3 Lithology

The lithology of the research area may also play a role in determining landslide susceptibility. This is due to the fact that lithological differences can influence whether a region is prone to landslides or has a low risk of landslides, particularly if the research area contains faulting structures.

There are three types of lithological units in the study area which are acid intrusive granite rock, Schist, and Gneiss. Furthermore, the lithology has been assigned a weightage of 7. The lithology map of Sungai Rual, Jeli, is depicted in Figure 5.3.

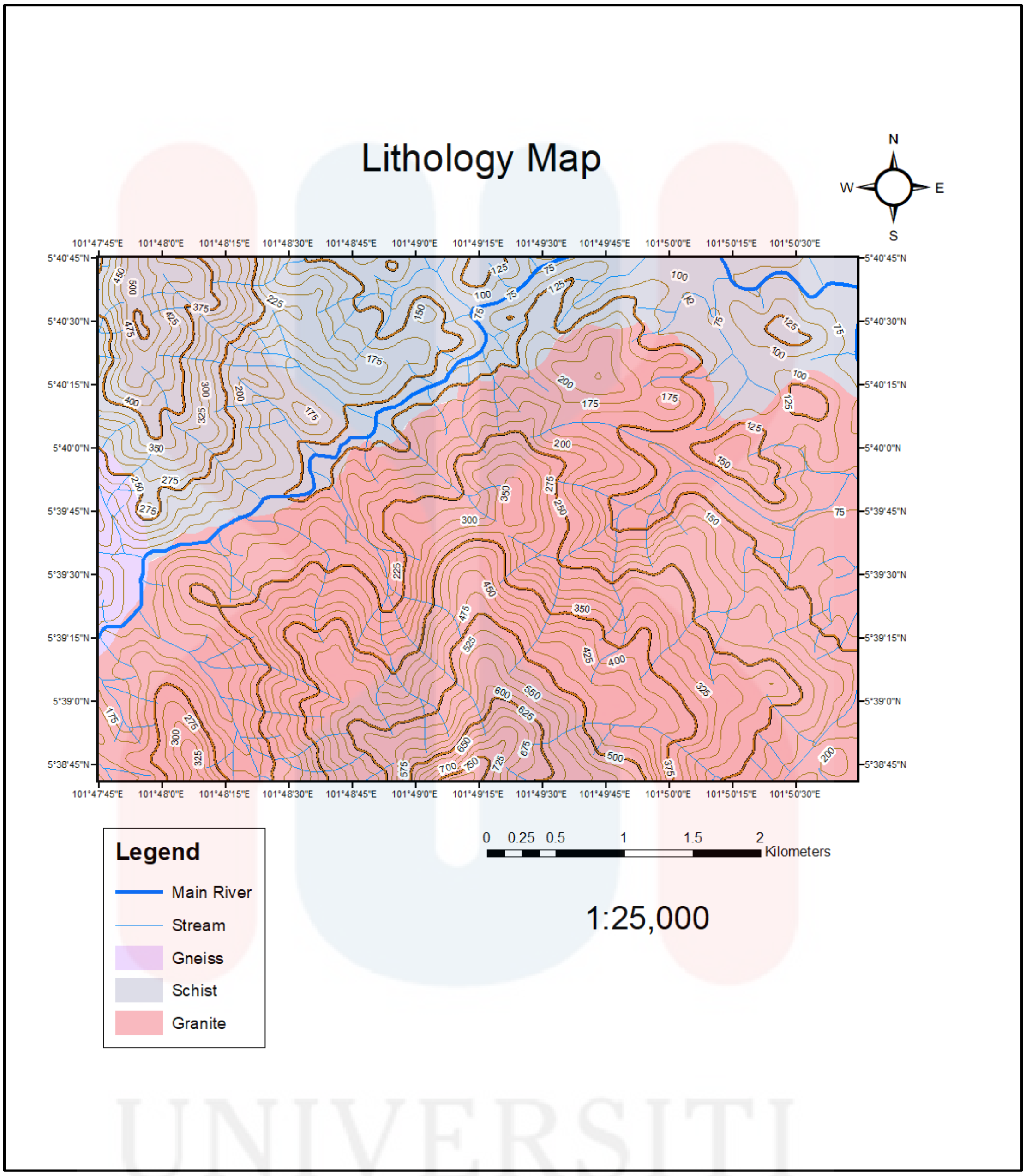


Figure 5.3: Lithology map of study area

5.2.4 Slope

The slope is one of the most important factors in determining the study area's susceptibility to landslides. The reason for this is that the stability determines both the frequency and intensity of the hazard study. This research site is situated in a mountainous terrain that is heavily influenced by the slope. Landslide occurrences can be greatly influenced by slope. As the degree of slope increases, the susceptibility to landslide increases because the force of gravity increases, and the steeper the slopes, the less friction force in the area, making landslides more likely.

According to Figure 5.4, there are six main slope classifications which are very gentle, gentle, moderate, moderately steep, steep, and very stee. On the other hand, this slope classification is done by referring to the Malaysia Slope Classification from the Geological Society of Malaysia, with a weightage of 10. (Table 5.3). This is due to its strong influence on the occurrence of landslides.

Table 5.4: The weightage and its score for slope

No.	Slope class	Weightage (Wi)	Score (Sij)	(Wi x Sij)
1	0 ˚ – 5˚	10	1	10
2	5 ˚ - 10 ˚	10	2	20
3	10 ˚ - 15 ˚	10	3	30
4	15 ˚ - 25 ˚	10	4	40
5	25 ˚ - 35 ˚	10	5	50
6	>35 ˚	10	6	60

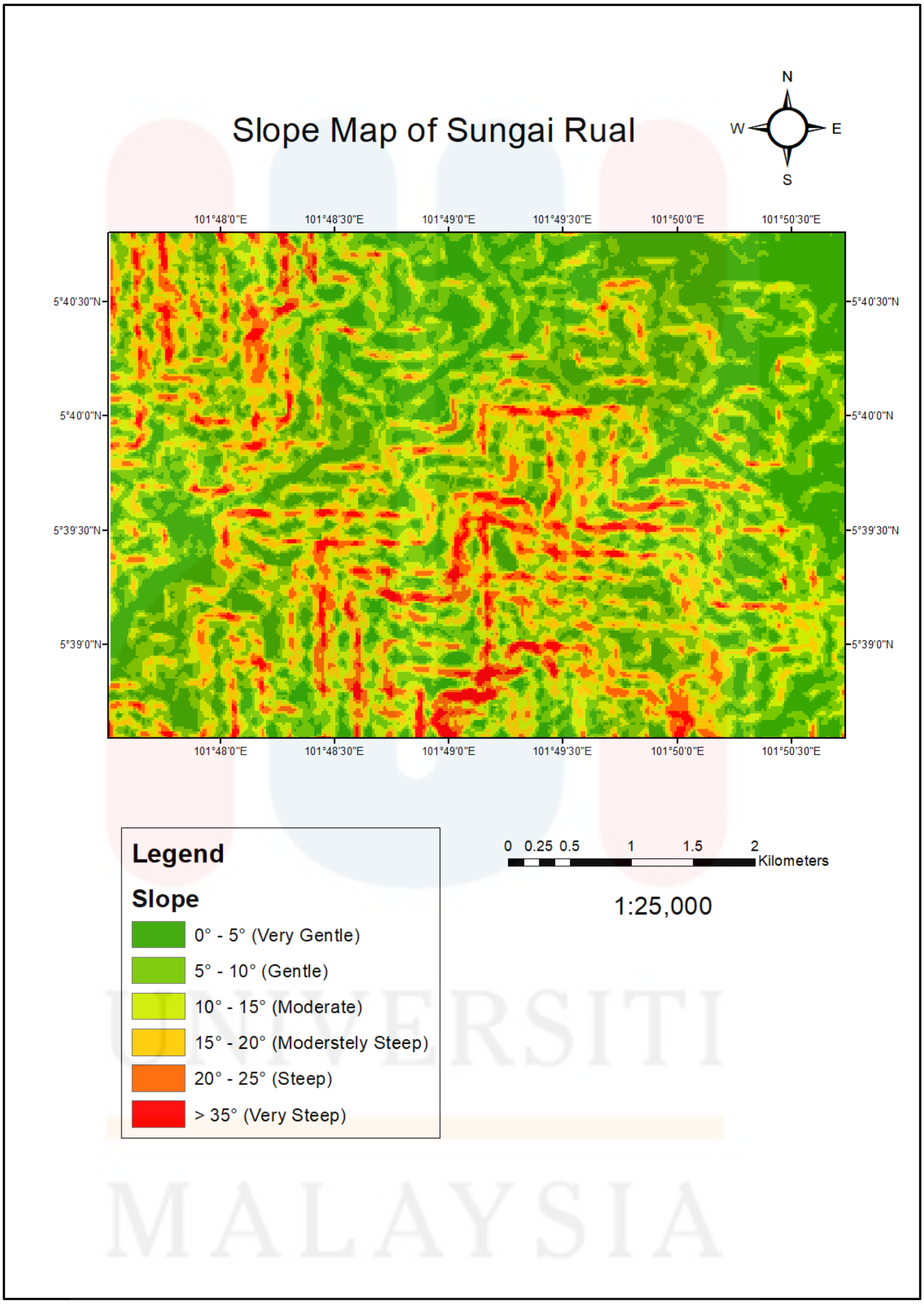


Figure 5.4: Slope map of study area

5.2.5 Aspect

An aspect map was generated using digital elevation model data. The aspect map classifies the slope direction as north into eight categories. The parameter was used to identify the slope direction, which can affect the gravitational force. This helps to determine the instability and direction of the slope. According to Lee, S. A. R. O., (2005) and Hadji, R. et al., (2006), the aspect is measured in degrees anticlockwise from 0° North to 360° South.

The aspect is a data type that describes the direction of slope development. Many scientists believe that the relationship between landslides and aspect is also influenced by the dominant wind direction (Wang, Y. et al., 2018). Other researchers, on the other hand, examine the effect of the aspect on landslides, taking into account the general precipitation direction, freeze-thaw, and sunlight in the region (Ahmed, B.,2015). According to Ramakrishnan D. et al., 2013 the aspect parameter has an indirect effect on landslides, based on the research conducted. This feature, along with other factors, is thought to play a role in causing landslides and different types of mass movements (planar, wedge, slope, and soil slide) are important for control.

Table 5.5: The weightage and its score for aspect

No.	Slope Direction	Weightage (Wi)	Score (Sij)	(Wi x Sij)
1	North	8	1	8
2	North-east	8	3	24
3	East	8	5	40
4	South-east	8	6	48
5	Southwest	8	6	48

6	West	8	5	40
7	Northwest	8	2	16
8	South	8	9	72

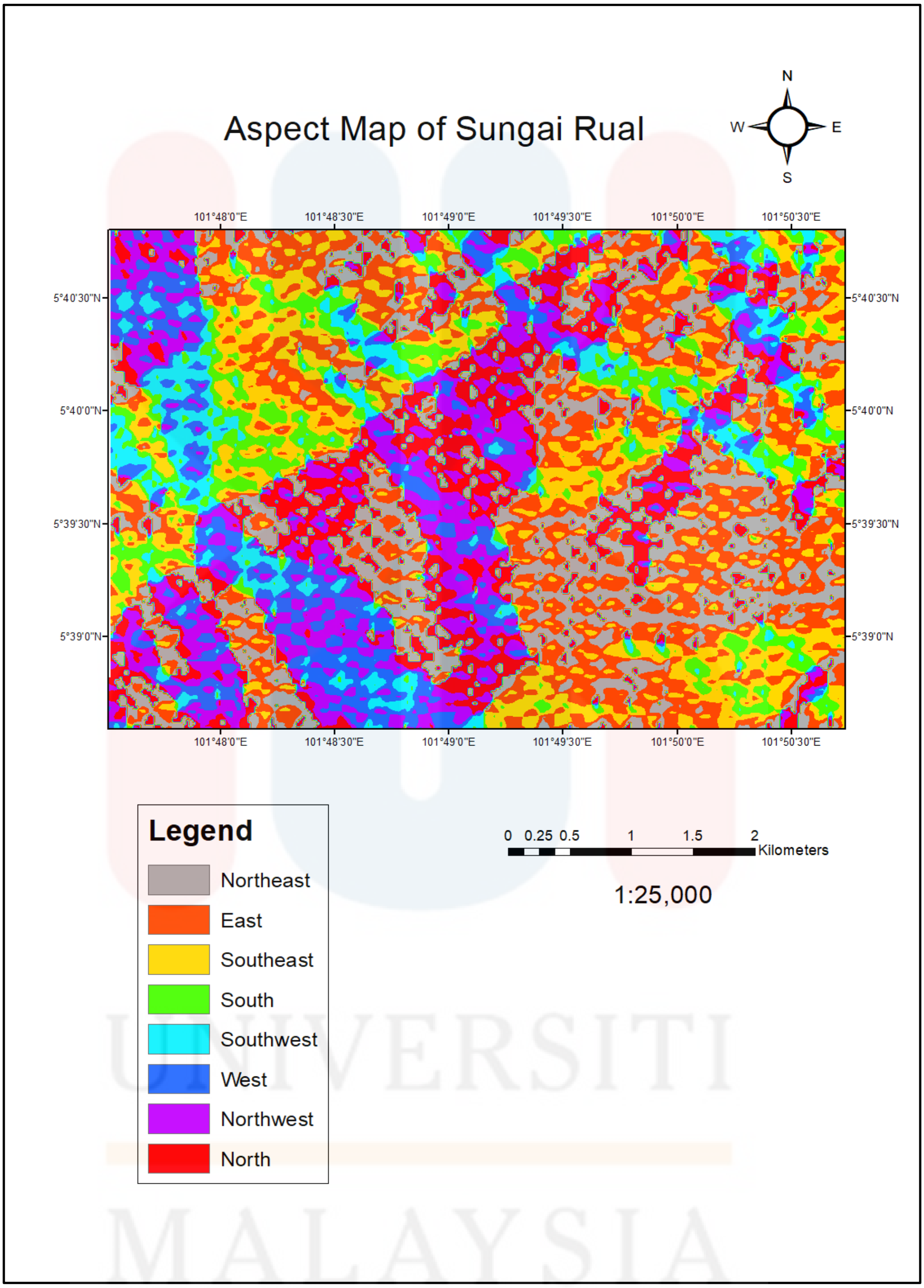


Figure 5.5: Aspect map of study area

5.2.6 Land use

The majority of the land was forest. Furthermore, some of the study area contains rubber plantation and grass land.

The amount of land cover, on the other hand, can determine the slope's stability. Furthermore, human activities such as logging of forest to build a building can hasten the occurrence of landslides and have a significant impact. As a result, according to Shaari, M. S. (2019) and Rodeano R., et al., (2017), the weightage for land use is given as 6, and the score is given in Table 5.6 below, while the land use is mapped in Figure 5.6.

Table 5.6: The weightage and its score for land use

No.	**Land use**	**Weightage (Wi)**	**Score (Sij)**	**(Wi x Sij)**
1	Forest	6	1	6
2	Wild Grass	6	2	12
5.	Rubber Plantation	6	4	24

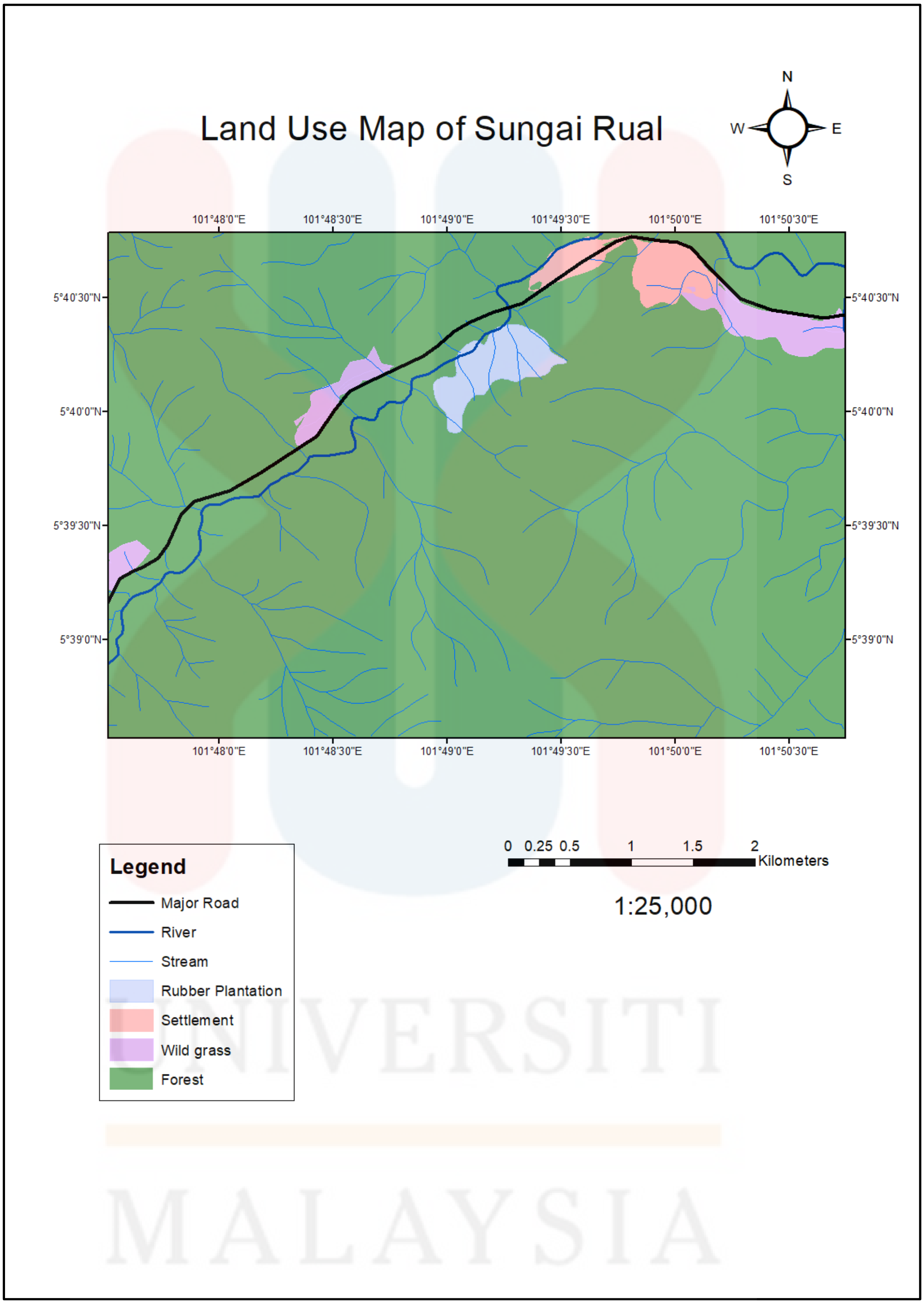


Figure 5.6: Land use map of study area

5.2.7 Landslide Susceptibility Map

The final result of this research was a landslide susceptibility map, which was created to highlight landslide-prone locations in three classifications such as low, moderate, and high risk. The map was completed by using the Modelbuilder, which is supported by the ArcGIS software, and it is capable of determining the landslide prone area. Six parameters were used to create this landslide susceptibility map which are distance to road, distance to stream, slope, aspect, land use, and lithology. The weighted overlay for all the parameters is done by Using ModelBuilder that is show in Figure 5.7.

Each parameter has been assigned a weightage value based on its influence on landslide hazards. According to Figure 5.8, the study area has been divided into three zones of landslide susceptibility in the study area, which covered approximately 56% of the area that has low susceptibility to landslide, 39% of the study area that is moderately susceptible to the landslide, and 5% of the study area that has high susceptibility to the landslide hazard.

In general, slope stability is the foundation for the frequency and intensity of landslide occurrences, making it one of the most important parameters in landslide susceptibility analysis. The steeper the slope, the more likely the instability. The hilly and mountainous regions have a higher risk of landslides due to their steeper slopes, which is why the study area was dominated by a moderate susceptibility area.

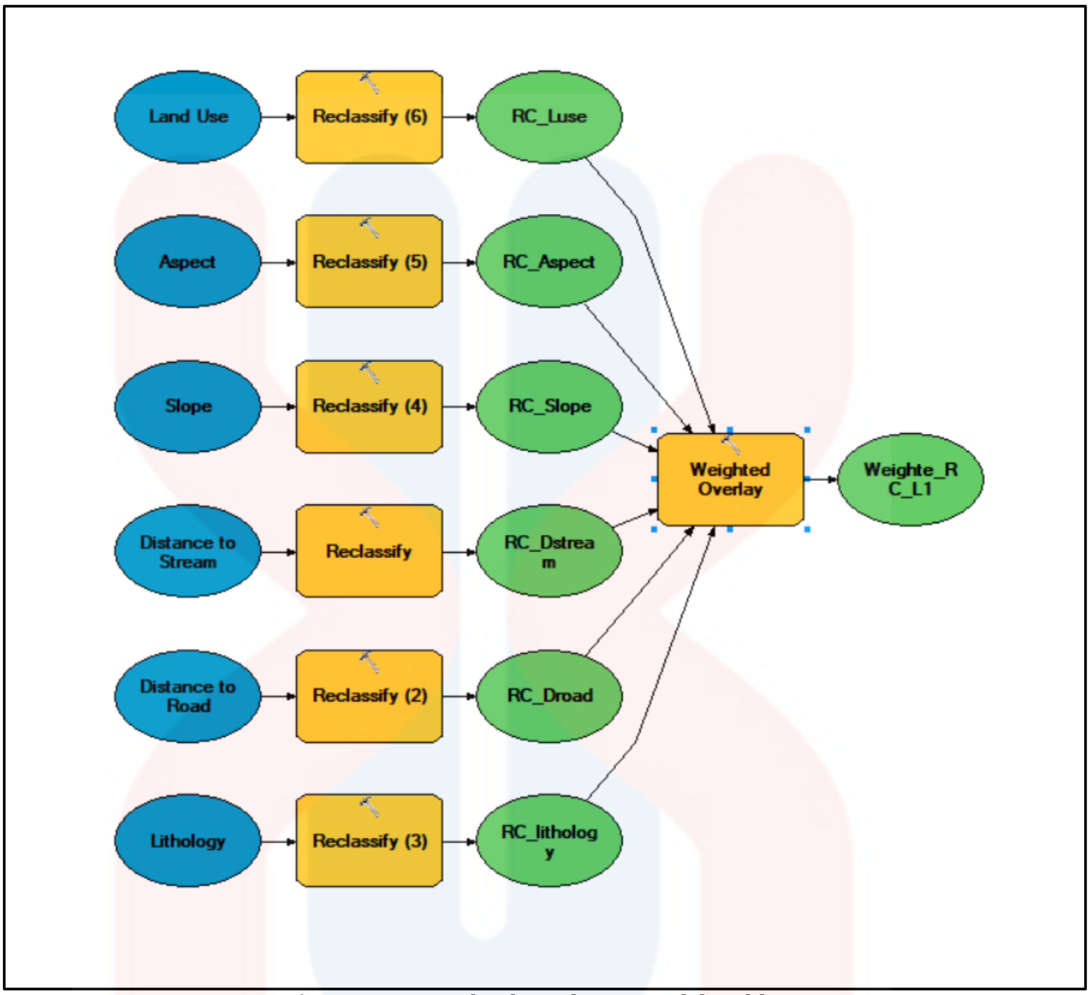


Figure 5.7: Weighted overlay in ModelBuilder

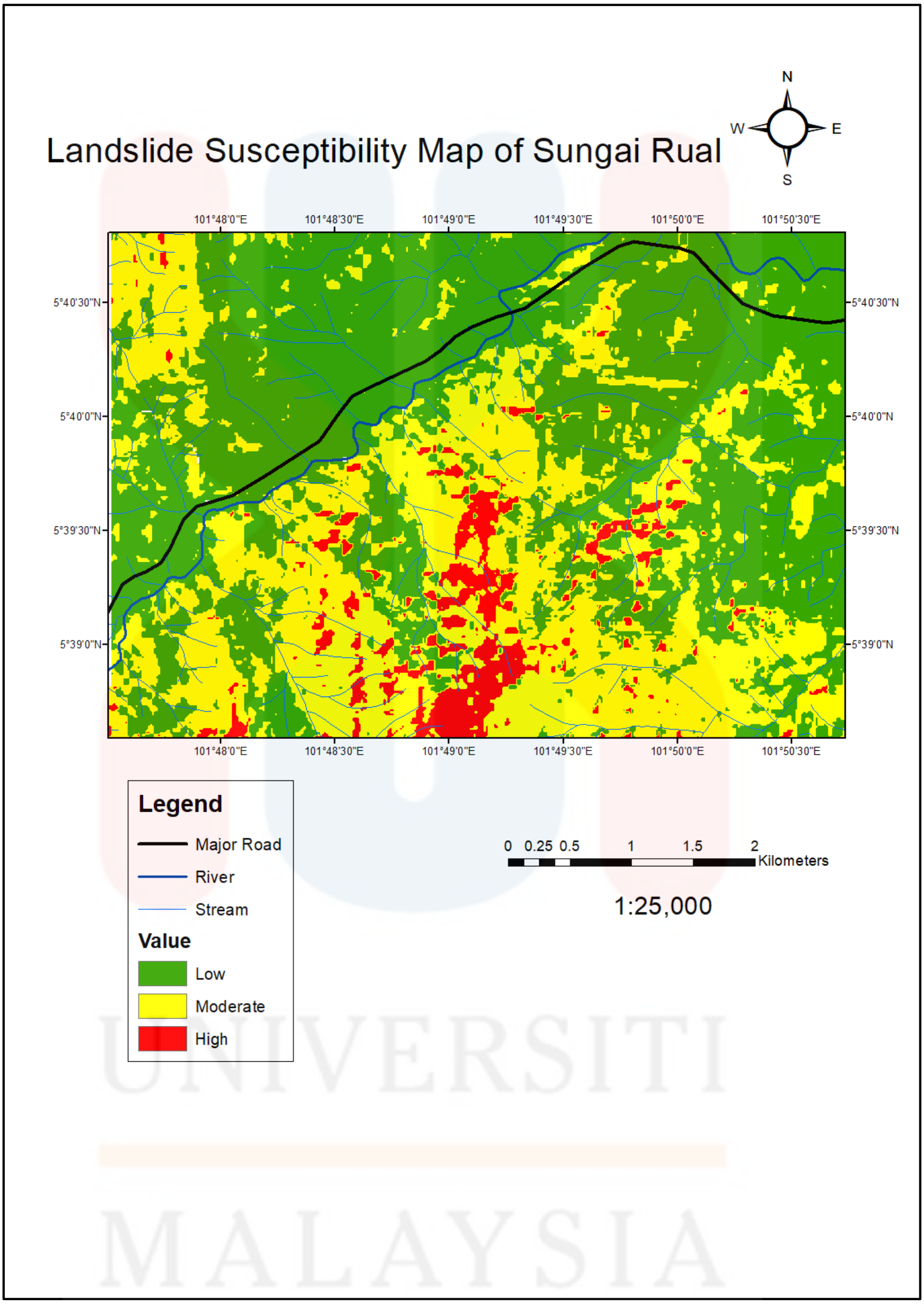


Figure 5.8: Landslide susceptibility map of Sungai Rual

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The geological map and the landslide susceptibility map is concluded in this chapter. Furthermore, this study has three main objectives which are:

1 To produce geological map of Kampung Sungai Rual, Jeli Kelantan with scale 1:25000.

2 To identify the parameters that influence landslides in the study area

3 To generate a landslide susceptibility map using ModelBuilder tool in ArcGIS.

Hence, all the objectives have been achieved successfully because the geological map of Kampung Sungai Rual with scale 1:25,000 is done as well as the landslide susceptibility map has been produced using ModelBuilder tool in ArcGIS by using six parameters that has been identified.

For instant, the first objective of this study which is to produce the geological map of the study area in Sungai Rual using scale of 1:25,000 has been achieved. The geological map has been produced in which the geological information and data such as lithology, structural geology and historical geology has been included in the geological map.

Geologically, there were two types of lithology sequence was found in the study area which are the acid intrusive granite rock, schist and gneiss. Furthermore, for lithostratigraphy, there are three period of lithology unit in the study area such as the youngest unit tertiary-aged intrusive rock that consisting of granitic rock followed by

Triassic-aged rock. This rock was formed due to exposed by erosion or other tectonic activity.

After that, Ordovician to Silurian-aged intrusive rock that consisting of schist and gneiss rock. In the area, the schist rock is found, and some acid intrusive granite was also found intruded in that area. Lastly, there is only small area that consist gneiss in the study area and all the type of rock were determined by using petrographic analysis.

While in the research specification, the objective was to determine the parameters that influences landslide in the study area and generate a landslide susceptibility map using ModelBuilder tool in ArcGIS Software. To generate the landslide susceptibility map, there are six parameters that has been used because they are affected the influences towards landslide susceptibility in the study area. This objective has been achieved since the Landslide Susceptibility map has been produced in Figure 5.8.

Overall, there are three classification of area that favour to the landslide occurrence which has been classified as low, moderate and high susceptibility to landslide. The study area also been separated into percentages, with low susceptibility accounting for 56% of the study area and moderate and high susceptibility accounting for 39% and 5% of the study area, respectively.

From the landslide susceptibility map in Figure 5.8, the area that has high and moderate susceptibility to landslide is mostly at the mountainous and hilly area. This is because, generally, the extreme rainfall events area commonly happened in higher elevation places, and then, the water flow will carry along the debris, soils and rock materials to the lower part of the mountain or hills. In addition, there are also higher drainage density at the mountainous area which has the same impact especially during the rainfall. Other than that, the mountainous area has higher degree of steepness compared to lowland and can cause the landslide due to gravity.

Lastly, lowland area has low susceptibility to landslide due to the slope which is more gentle or less steep, thus there is lower gravity effect towards the lowland compared to the hilly and mountainous area. Also, the elevation of the area is also lower than hilly and mountainous area. In addition, the drainage density of low land is not as dense as the mountainous area making the area less vulnerable to landslide.

6.2 Recommendation

For the geological and specification part, it is advised to do the next research by going to gather more geological data in the field and ensure that the data is accurately been taken. This is because primary data are more reliable and precise if we take it from the field. In addition, the study that uses satellite images does not compatible with the real landscape, feature and structure. Furthermore, there are a lot of data deficiency while doing the geological mapping and landslide susceptibility mapping.

Further petrography of igneous and metamorphic rocks in this area is recommended as petrography research still lacks due to acid intrusive occurrence that made petrography study is complex and bit difficult in studying tectonic behavior in this area.

In addition, more samples should be taken in order to cover up entire study area by that, complete geological data can be produced by rocks types and its units. Then, data and result from next research study should be compared and updated to ensure accuracy of data to benefits the communities and researchers from other fields.

Apart from that, the landslide susceptibility mapping is recommended to apply kinematic analysis method for the landslide study as it is tend to be more accurate since the data were freshly taken and observed from the field activities. Then, it will be more accurate if the parameters used for landslide susceptibility mapping is a lot more than this study such as the rainfall distribution and soil type because different types of parameters may provide different results, the results can be compared to determine which parameters had the greatest impact on the research area's landslide susceptibility.

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